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A REPORT

ON

IRRIGATION

AND

THE CULTIVATION OF THE SOIL THEREBY,

WITH

PHYSICAL DATA, CONDITIONS, AND PROGRESS WITHIN
THE UNITED STATES FOR 1891,

ACCOMPANIED BY

MAPS, ILLUSTRATIONS, AND PAPERS.

BY

RICHARD J. HINTON,
Special Agent in Charge,
OFFICE OF IRRIGATION INQUIRY, DEPARTMENT OF AGRICULTURE.

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LETTER

FROM

THE SECRETARY OF AGRICULTURE,

TRANSMITTING

The final report of the artesian and underflow investigation and of the irrigation inquiry.

FEBRUARY 4, 1892.—Referred to the Committee on Printing.
FEBRUARY 17, 1892.—Ordered to be printed.

DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., February 4, 1892.

SIR: I have the honor to transmit herewith the final report of the artesian and underflow investigation and of the irrigation inquiry, as conducted under my direction in pursuance of authority conferred by act of Congress approved April 4, 1890, and an act approved September 30, 1890, and an act approved March 3, 1891, and to state that it was fully completed and deposited in accordance with the terms and conditions of the last-mentioned act.

I have the honor to remain, yours respectfully,

J. M. RUSK,
Secretary.

The PRESIDENT OF THE SENATE.

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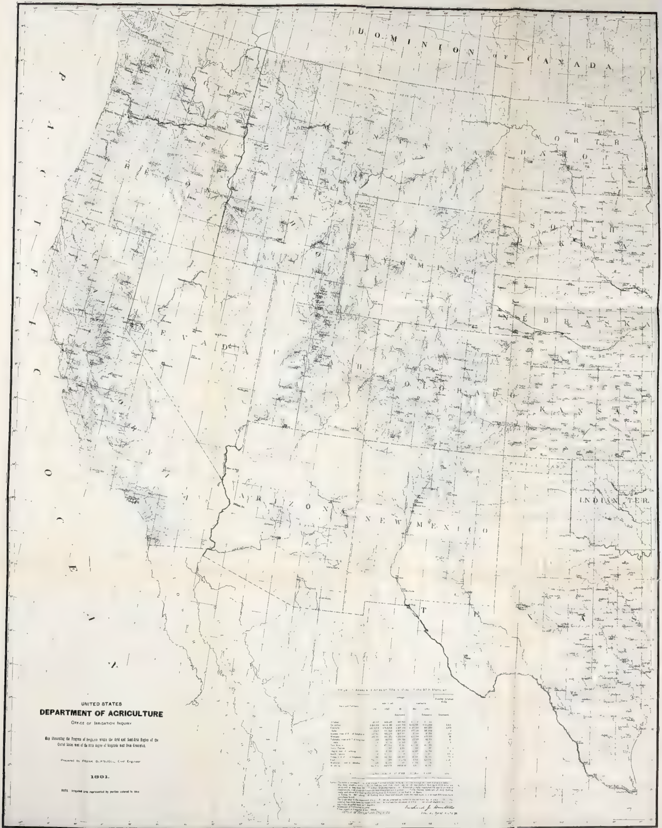

UNITED STATES
DEPARTMENT OF AGRICULTURE
OFFICE OF IRRIGATION INQUIRY

Map Illustrating the Progress of Irrigation within the Arid and Semi-Arid Region of the United States west of the 97th degree of longitude west from Greenwich.

Prepared by FRANK BLAISDELL, Civil Engineer

1891.

NOTE. Irrigated area represented by portion colored in blue

A REPORT ON IRRIGATION, AND THE CULTIVATION OF THE SOIL THEREBY.

INTRODUCTION.

During the past year, under the direction of the Secretary of Agriculture, the office of irrigation inquiry has endeavored to obtain as comprehensive a view of the conditions of "irrigation, and the cultivation of the soil thereby," as the means appropriated would allow. In the work of the office itself an endeavor was made to systematize the mass of information, data, reports, and papers at its command. That this work has not been entirely completed is due to the pressure of other duties. The increasing correspondence has borne heavily upon the small force employed. This correspondence shows the rapidly growing interest and attention that is being aroused by the whole subject of water management in connection with agriculture. A steady demand has been made for the reports published in relation to the work of the office. This demand has been so great that it has been impossible, with the limited editions issued, to respond to one in fifty of the requests made for the Progress Report of 1891 and that of the report on artesian wells made in 1890. Of the latter report Congress ordered printed its usual edition of 1,734 copies. The Department, for official use, purchased 100 copies, which is all that were at its disposal. As an illustration of the value accorded to this report, it may be stated that dealers in Government publications have been holding a few copies that they obtained at the rate of $2.50 each. Of the Progress Report, Parts I and II, in addition to the ordinary Congressional edition, the Department purchased from the Public Printer 1,500 copies. This number has long since been exhausted, and there are a large number of names on file in the office as evidence of the requests made for the copies of these two reports. Many of these requests are from distinguished foreign engineers and experts, Government officials, and librarians.

During the year past this office has sent out several thousand circulars for the purpose of obtaining the latest data, the responses to which have been more than usually numerous. In face of the fact that requests of a similar character have been circulated by several bureaus and officers belonging to another department, the responses received by the office of irrigation inquiry were gratifying in number and character.

Early in the year it became evident that the work of the inquiry, to be of full value, must be personally directed in the field. It was decided by the Secretary that the special agent in charge, accompanied by an assistant, should visit the several States and the areas within them in which irrigation works are in operation and progress. This conclusion was reached upon the conviction that the work would be more thoroughly accomplished in this wise than by the employment of local agents over whom only a distant and insufficient supervision could be had. As a result of this determination, the special agent left Washington early in May and returned the latter part of July. During the eleven weeks of that absence himself and assistant, traveled by rail about 14,000 miles and by private conveyance some 1,500 more, visiting the most important irrigation centers and districts in the States of Kansas, Colorado, Texas (west of 97°), California, Nevada, Oregon, Washington, and Idaho, as also the Territories of Oklahoma, New Mexico, Arizona, and Utah. While on this journey some forty irrigation districts and centers were visited and inspected; the plans, reports, and maps, etc., of leading organizations were obtained, and the testimony of about 300 persons actively interested in the organization and management of irrigation enterprises was obtained. This testimony, condensed and summarized, is presented in this report.

One of the most notable instances of the past year has been the interest aroused in this subject in sections of the Union that are most largely affected by heavy precipitation and constant humidity. From the South, for example, there has been received a large amount of information on the subject, illustrating the fact that in such States as Louisiana, Alabama, and Texas, the semi-tropical heat of the summer, with its attendant evaporation, tends rapidly to produce drought in the growing season, and as a consequence thereof materially affects the security of the important commercial crops which are grown in our Gulf States. The irrigation problem in Florida gives evidence of being a very interesting one, especially in the eastern part thereof, where artesian water by means of wells can unquestionably be utilized to make secure the orange orchards and vegetable gardens whose productions form so valuable an industry in that State. The evidence and information which has been sent to this office from these and other States has been carefully collated and arranged and is herewith presented. More recently a number of inquiries have been received from the New England States. Another inquiry consists of systematic observations made under the direction of Mr. Howard Miller, special agent of the Department and this office, as to the volume of water, its rise and fall, that may be found and recorded at stated periods of each day in a series of railroad wells, lying along the Kansas branch of the Union Pacific Railway west of Wa Keeney, Kans. The object of these observations, which it has been expected may be conducted through a period long enough to make reasonably sure of the conditions affecting the inlet of the water into the wells, is to ascertain the extent of phreatic draining in the region covered by the observations. It is the principal portion of the area in which what the geologists term the "rivers of the plains" take their rise. The railroad along which the wells are directed passes across a section of the great plains in which the head waters of the Republican and Solomon rivers, the principal branches of the Kansas, make their first appearance on the surface. At moderate depths below the surface, though not always to a regular degree, a gravel stratum is found saturated with drainage waters. In most instances the wells under observation terminate their shafts in this gravel stratum. It will be a matter of great value to be able to ascertain the ebb and flow, if any such exist, of this drainage or phreatic supply.

Mr. Howard Miller's first report, which forms part of the present one, will be examined with interest. Another paper of very considerable technical value is that of Mr. C. E. Grunsky, C. E., formerly assistant State engineer in California. Mr. Grunsky's paper, the result of several years' continuous study of the conditions affecting irrigation in the San Joaquin Valley, will prove of general interest to all irrigationists, and the ample and clear illustrations which accompany it of the methods and works employed render it of the greatest practical value to all interested. In addition to these papers, a translation of several chapters from a work on "agricultural hydraulics" by the French expert, Charpentier de Cossigny, has been prepared for and accompanies the special agent's report. A very condensed review prepared by him of irrigation conditions in foreign countries is also added.

The principal map attached to this report, constructed from data carefully gathered by the special agent in charge and the office of irrigation inquiry under him, is designed to present as an object lesson an illustrative statement of the progress in areas and acres of the work of reclamation by irrigation in the arid and semi-arid region west of the ninety-seventh meridian of longitude west from Greenwich. It serves to show not only the progress of irrigation itself, but the manner in which the American pioneer has been and still is in the habit of seeking and obtaining under his own inspiration and judgment, a home upon the public domain, and by his own efforts in combination with those of his neighbors, organizing industrial security for his home, himself, and his family. There is another lesson to be learned from this map, and that is, that the progress of such settlement and reclamation as it exhibits is also steadily increasing our knowledge of the water supply, while it is steadily tending to encourage the investment of capital in the work of agricultural reclamation and cultivation by means of irrigation. In this wise the use of water is proven to be the conservation thereof. It will be observed that the areas of cultivation along the principal water courses and within the drainage basins are growing in extent quite rapidly. This is a proof of the improvement in character of the works constructed, and in the methods of supply, means of administration, and the distribution of water. With these larger areas will be found a numerous body of very small ones, almost beyond recognition upon the scale allowed for the map, but from which the observer and student can see that the hardy pioneer is pushing across every mountain basin, through foothill sections, and up all the small valleys, seeking surface and underground supplies from which he may obtain water sufficient to make fertile the wild and waste lands which need only the touch thereof to make "the desert bloom and blossom as the rose."

WORK ON THE GREAT PLAINS AND THE RESULTS.

The final reports of the artesian and underflow investigation were completed as the law required. The thorough and comprehensive character of these reports, with the series of maps and profiles and illustrations that accompany them, is apparent on the most casual examination. The work of correlating effects and results which necessarily fell upon the special agent in charge, whose duty it has been to note the same over the whole field of inquiry, warrants him in stating that the direct as well as the indirect results, the latter of which are to be felt hereafter even more positively than at present, show that no expenditure on the part of the General Government has achieved such large and immediate benefits for so small a cost.

During the season of 1891, additional interest was aroused by the irrigation of two farms in South Dakota with artesian water, under the direction of the chief engineer of the investigation. By this means systematic instruction was given, which so greatly encouraged the farmers and the people generally, that capital remained that was preparing to withdraw, and new investments have been made on every hand. In a certain degree, the same state of things appear in all the other States, covered by the artesian and underflow investigation. In Nebraska, where, in 1890 there was not a single irrigation enterprise in practical operation, there are now several scores of separate works under way in the western counties, by means of which a large area will be brought under cultivation, heretofore given over entirely to stock. In western Kansas the beneficial influences, direct and indirect, have been as strongly felt as in the Dakotas. When the work began, in 1890, the counties west of the one hundreth meridian of longitude were in danger of being entirely abandoned for agricultural purposes. As, however, the existence of the underflow waters in the valleys of the Arkansas and Republican rivers in Kansas, of the South Platte in northeastern Colorado, and the North Platte in southwest Nebraska, were being established by the assiduous labors of the investigation, the fears caused by the recurrent drought have ceased. The existense of underflow or phreatic waters at varying depths and quantities throughout the length and breadth of the great plains region has been in a large degree tentatively established by its work, and that fact has given great encouragement to the pioneer farmers and communities in western Kansas. Encouragement has also been given, by the large work done during the past twenty-one months, to agricultural enterprise and industry in southwest Colorado, in eastern New Mexico, and throughout Texas west of the ninety-seventh meridian. The practical work of construction and cultivation which is in progress has resulted in great part from the impetus given to energy and enterprise by the same influence under the small appropriations made by the Fifty-first Congress.

In an address made to the students of the North Dakota Agricultural College, and to other bodies in South Dakota, in the month of March, 1891, by direction of the Secretary of Agriculture, the special agent endeavored to sum up the economic possibilities of the investigation under consideration. He said:

> For my purpose I assume, temporarily at least, that the reclamation of the great plains is not to be accomplished by any great system of water storage. I assume, also, that, taking the plains as a whole, great systems of canals and other large surface works will not be a necessity. I am, of course, cognizant of the fact that there are large areas in which surface storage and distribution on an extensive scale may be required—indeed become a necessity, but the reclamation of the division I have outlined, the 700,000 square miles defined as the great plains, is to be accomplished by a multitude of small detailed works, and must in the end be largely the result of neighborhood and individual exertion. Along the broad valleys of some of the rivers that infrequently cross those plains, there will necessarily be both surface and subcanals or ditches on a large scale. But the security of the agriculturist is to be chiefly accomplished by small farm storage, by the impounding of the little streams, by the utilization of springs, and by the restoration to the surface through artesian drills or by the mechanical lifting from other bored wells, of the waters that are stored below the surface soil in the earth itself. The strata below that soil are for great distances a series of huge sponges, wherein the lost, imbibed, and percolated rainfall will be found to be stored.
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> * * * * * * *
>
> There is not then a farm of 160 acres in extent as now located upon the great plains region upon which the farmer need fail in the worst year of drought to obtain a living for himself, family, and stock, keeping free from debt also, provided he will utilize the small natural supplies of water beneath his feet, and content himself at first with direct cultivation of only so much of the land in his possession as may be nec-

essary to make certain the supply indicated. The rainfall everywhere appears to be so conserved by the nature of the known stratum beneath the soil that any man with a quarter section can secure and distribute the requisite moisture, that may be absolutely needed for from 10 to 30 acres of tillable ground. I am talking of the day of small things and beginnings, and urging the consideration of security therefor. Thirty well tilled and watered acres will feed and care for family and stock, and will also enable the plains farmer to enlarge and take better care of his stock, thereby increasing income and aiding him to obtain in the near future and as necessary a greater share of a more permanent water supply.

WATER CONSERVATION AND MANAGEMENT—THEIR SCOPE.

The more thorough the investigations conducted by this office have been the wider and more comprehensive the field became. It is perceived that the natural phenomena and conditions relating to the cultivation of the soil by irrigation extend far beyond the mere limits of reclamation or agricultural economics in the region affected by a deficiency of rainfall and humidity. The problems underlying the subject relate themselves to the greatest of physical and cosmical facts. They make a draft on the one hand upon the sciences from topography to chemistry, and on the other hand, they embrace somewhat of all the great economic factors which go toward the solution of largest sociological problems. Systematic irrigation involves not only successful reclamation, but it embraces intensive cultivation, small farms and orchards, largely increased and specialized production, intelligent direction under the educated brain and trained hand, with the massing of cultivators into highly organized communities. Important as are the influences involved in these conditions, they by no means include the most significant of the problems that arise. More and more the conduct of the investigation and inquiry that has been committed to this office tends to prove that a right understanding of the magnitude and character of all that is included in water conservation and management must be a necessary condition of successful agriculture. One statement made by Geologist McGee at the Washington meeting of the American Association for the Advancement of Science, will serve to illustrate this. That gentleman described a professional trip through Mississippi. Over one-fifth of the area of that State, if recollection serves aright, was stated to have been rendered unfit at present for cultivation; first by the reckless destruction of the timber, and next by the torrential effects upon the soil of the heavy rainfalls. The denuded land had been torn into gullies and ravines, and thereby became worthless for industrial use. The decrease in the level of the Great Lakes, which is generally accepted as a result of deforestration, is another evidence of the want of proper knowledge in dealing with the earth and its laws. The destructive floods of the Mississippi and Ohio rivers are also in proof. The effect of excessive humidity of undrained lands, and the existence of marshes and similar areas, all belong to the largest problems involved.

The utilitarian and hygienic factors connected with town and city water supplies are a part of the work that some day will be correlated and directed with the observation of other and related phenomena and conditions, under the direction of the Department of Agriculture. A knowledge of the laws of climatology will establish conclusively that irrigation combined with drainage—that is, of water management in the large sense—is an absolutely necessary condition of successful agriculture. It is seen by even a cursory examination of the facts that the conservation and distribution of water may be made as serviceable in obtaining security for crops where the rainfall is excessive as it must necessarily be in making possible the reclamation of arid lands. The question of heat and consequent evaporation far more than rainfall during a given season will decide whether or no a growing crop will be fully matured. Many questions besides the more simple ones involved in the act of applying water to the soil are bound up in the problems of surface conservation and management, as well also in the conditions of earth or phreatic waters. It is remarkable how very little is known as to the extent or character of controlling phenomena in the matter of subterranean water supplies. Even the examinations made by the artesian and underflow investigation, simply objective as they have necessarily been, go a long ways towards disturbing pre-accepted theories of artesian and drainage supply. The rise and fall of the subwater plane in cultivated valleys or other areas is one of the conditions which at no distant date the physicists engaged in correlating for economic uses such phenomena as are here suggested must take into serious consideration. Two years since, for example, it has been stated, that in Hocking Valley, Ohio, a region which is certainly not deficient in rainfall, the entire water plane, as shown by the wells sunk from 20 to 40 feet below its usual level. The continued changes going on beneath the crust of the earth projects a speculative inquiry, which may, however, have something of importance in it, as to how far the disintegration of rocks and strata may affect the phreatic supply. Water forms a large proportion of all rocks or strata. Again, no one has any systematic knowledge of the extent, egress, or ingress of subterranean channels and the volumes of water they convey to or from the ocean. The British Government printed, among other papers relating to the famous explorations of the ship *Challenger*, one by the chemist of the expedition, which, with maps, is designed to illustrate the density of the ocean waters at various depths and conditions. In this paper attention is called to the fact that a greater proportion of solid matter is found held in solution in such portions of the ocean as are regional with the arid sections of Asia or Africa. In other words, it is indicated that the fertilizing qualities of the soil have long been systematically washed through silt-bearing streams in enormous quantities into the ocean itself. Surely, then, the whole subject of agronomic hydraulics presents features of the greatest importance.

But the work of this office was defined and, in an indicative sense, limited by the terms of the law, in virtue of which it was organized by the Secretary of Agriculture. Its work has been directed by very simple yet comprehensive terms, and demands an inquiry "into the cultivation of the soil by means of irrigation." To that end this report now directs itself.

STATE SUPERVISION OF IRRIGATION AND WORKS.

One of the serious problems pressing steadily for consideration is that involved in the question of supervision over works and water supplies by the States interested in the reclamation of arid lands. At the present date there is not a properly equipped State engineer's office or board of water control in existence. Only two States have engineer officers with any powers approaching the needs of hydraulic administration. One other has provided for the supervision of artesian waters. The work of such oversight and control must be done by the States themselves; first, through a competent engineer's office or board of control, of which the engineer shall be a member; and second, by the establishment of municipal subdivisions, administering through popular control by practical experts the water supplies at the command of the district. Irrigation construction and administration is not a matter for haphazard movements or mere speculative endeavor. It involves, practically, the organization for Americans of a new system of agriculture. In the progress of that system it is certain that great profits are to be achieved. It is equally as certain that the irrigation cultivator must be a person of intelligence, of keen capacity, a faithful student, and untiring worker; otherwise he will be left in the race. It is already indicated in such a degree as to point to an almost positive result that the effect of systematic reclamation within our Western States will be a great subdivision of land holdings. As a necessary consequence of such subdivision the isolation of farm life will vanish, and agricultural or horticultural town or village centers will become a marked feature of settlement. The character of works to be employed, the facts of climatology, the relations of the atmosphere to the water and the soil, the adaptability of the plants to different zones, and at least a primary knowledge of hydraulic engineering will become a part of the training of every successful cultivator of the soil by means of irrigation. The administration of the water supply involves subtle questions of law and economics, and goes for illustration back to the very dawn of history.

All communities, the cultivation of whose food products has been achieved by the artificial application of water to the soil, have in a more or less elementary manner been compelled to organize some form of governing the water-using people, directing and controlling the constructions needed for the storage and conservation and distribution required for the purpose of tilling the land. The Pueblo Indian and the Mexican farmer alike appoint or elect their local water masters and submit themselves with great faithfulness to customs and provisions more or less stringent in character. An examination of the habits and customs of all communities long using irrigation brings to view the same condition and establishes the same order of procedure. It is evident from even a cursory study of the great hydraulic systems of ancient days in Mexico, in South America, in Northern Africa, or Arabia, or throughout the great oriental countries, that the most elaborate codes of laws were established by the central authorities, whatever character they may have been, and that these were supplemented by local regulations, a great many of which have survived to the present times in the rehabilitation or recreation of these great works. In Egypt, Ceylon, and British India the same necessity of rigid supervision and careful administration has been imperatively settled. In the British Australian colonies of New South Wales, Victoria, and South Australia, the discussions show a full appreciation of oversight and control.

In New South Wales, Queensland, Victoria, and South Australia departments of water supply have been organized. The two first-named colonies have in their employ a body of able engineers and other professional men, whose duties are directly associated with the conduct of the water trusts authorized for irrigation and for domestic purposes. They are also charged with the study of climate, geology, topography, and forestry in connection with the requirements of a proper conservation of the property held by the state in the natural waters. Queensland has recently undertaken through its water department a systematic series of borings for an artesian supply. Victoria and South Australia have made extensive contracts with well-known American organizers for the reclamation of 250,000 acres in each of the colonies named. The maps and reports that have been prepared and published by these colonial governments are among the finest and most thorough of their character issued in the world. In Victoria especially no extensive system of irrigation can be inaugurated except upon plans approved by the government engineer, while the construction of the works required is carefully watched by the water supply of the department. Of course it is true in these as in other parts of the British dominions, where the storage of water is a necessity for successful agriculture, that questions of statecraft in the way of colonization, maintenance of peace over subjugated races, as in India, and methods of insuring loyalty to the mother country are all involved in the plans which have been adopted alike in South Africa, Ceylon, India, and the Australian countries.

The general existence of all these tendencies is pointed out not by way of argument for any plan or scheme or policy, but in order to illustrate what seems to be the natural and necessary law controlling irrigation work and the communities connected therewith. In the States west of the ninety-seventh meridian upon this continent, so far as any action has been taken it is to provide for the right of appropriating the water, to give a means of legal appeal in case of contest, and to leave all the rest to the friction of an aggressive and struggling existence. California has relegated, and very efficiently, local construction and distributive supervision to the communities interested. Several other States have in part followed this lead. But the laws establishing such a system touch in nowise upon the greater needs, soon to be pressing ones, involved in the demand for water storage for the protection of river and stream sources, for the insurance of security to life and property, by compelling proper construction in the great storage works that must be built ere long, for the enforcement of systematic drainage in the interests of health as well as agricultural economy, and for the proper dealing with a thousand other important questions that might be marshaled here and that can not safely be left to the accidents and emergencies that arise from a day-by day avoidance of public obligations. The Utah settlers, who first organized neighborhood systems of irrigation upon an extensive scale within our boundaries, have, by the peculiar nature of the obligations that control them, succeeded, without definite codes of law or even an efficient water police, in coöperatively maintaining equity among the users. Nowhere else, except in the survivals referred to among the Pueblo Indians and Mexicans, or in the new organization expressed in the California districts, have we begun to reasonably realize the needs involved in this matter of State control of local supervision. The constitution and laws of Colorado have been directed almost wholly to securing the rights of appropriators, the freedom of conveyance, and a reasonable method of settling disputes while proclaiming the public character of water property. The State of Wyoming, modeling its legal action upon that of Colorado, has also simplified and improved upon it. So far as the protection of appropriation, the guarding against this undue and unjust exercise, and the control of ditches in that direction, its State board of control and the engineer's office are better equipped than elsewhere is the case. Consideration of the questions involved in these suggestions must ere long be seriously taken up.

THE GROWTH OF RECLAMATION FOR 1891.

The year 1891 has been marked with great activity in the direction of reclamation enterprises on a large scale, and in the development by means of irrigation of numerous small localities west of the one hundreth meridian. This beginning of cultivation, generally upon small areas of land, is even a more notable illustration of economic progress than the organization of great enterprises whose works are designed to ultimately reclaim and bring under use several millions of acres of land not now adapted to agriculture. If the lines of cultivation and migration during the year 1891 were laid down upon a map, they would show within the arid region of the United States movements so defined as to make a distinct parallelogram. In the region between the ninety-seventh meridian and the foothills of the Rockies, almost from north to south, there has been a decided growth of settlement and a marked increase of cultivation. The more distinctly this growth has been brought under the influence of irrigation development, however supplied, the more certainly it shows evidences of permanent prosperity.

The increased feeling of security in the Dakotas has been followed by as marked an increase in acreage and production. The Black Hills portion of South Dakota, for example, has almost escaped attention during the pendency of the present inquiry and discussion. In 1889 it was estimated that some 13,000 acres were cultivated chiefly for forage and cereals, by means of irrigation supplied by small ditches. In 1890 the area so cultivated was estimated at 20,000 acres. In his final report as geologist for the Dakotas in the artesian and underflow investigation, Prof. Garry E. Culver places the area of irrigated lands in the Black Hills section at 50,000 acres. In Nebraska and Wyoming, moving southward on the eastward line of the parallelogram, there will be found to be a considerable increase of population and a much larger proportionate increase of effort in the direction of extending reclamation works over the arid lands. The estimated area of increase for the year in Wyoming is 856,700 acres. That of Nebraska, for works partially finished or in progress, shows an estimated increase of 135,000 acres under ditch and of 30,000 acres under cultivation.

The public feeling is turning strongly in the direction of a smaller number of acres and a more careful cultivation, with an eager desire to secure, whenever possible, an independent water supply by which to make farming operations secure. Another marked feature of business enterprise and public opinion is to be found in the fact, as indicated by discussion in the press and the correspondence of this office, that the officers and managers of mortgage companies and of farm-loaning banks all express themselves as most eager to aid the development of water supplies under such circumstances as will assure upon the Great Plains the disposal for cultivation of the lands they hold, or control as security, in areas much less in extent than has heretofore been held in that region.

Both north and southeastern Colorado have been benefited by the movement under review. Many small enterprises are also recorded in the eastern portion of that State. A special development of eastern Colorado is the growing interest and effort in and for the establishment of reservoirs, both large and small. The valley of the Arkansas is marked by the progress of a number of great enterprises, one of which is distinguished by its efforts to utilize open basins and depressions south of the river for storage purposes. One engineer reports seeing in the eastern portion of the State from an elevated point 134 storage basins, small lakes, or ponds all lying within the range of his vision. One of the chief objects of this effort is to obtain a supply for and store the same during the winter months, so as to be able to keep the ditches running when planting begins in the spring. The discussion of the past three years over the advantages and needs or otherwise of storage reservoirs has certainly developed some features of hydraulic engineering which, when the discussion began, would have been considered audacious in character. In spite of the arguments relative to loss by evaporation and the wates claimed to follow all attempts to bring mountain supplies long distances without high altitude storage, the tendency is quite marked towards a development of storage basins upon the open plains. Something of this is due to the increase of knowledge which has followed the artesian and underflow investigation as to the extent and condition of precipitation over such large areas of land free from mountain range and gradually passing into the prairie formation. It has become apparent, under the close local observation which has been aroused, that if the local precipitation can be thoroughly conserved it will with the current daily rainfall go far towards supplying the needs of the farmers of table-lands and plains. Experimentation in such directions is a necessary feature of its development and progress. As a result of all this there is already a considerable increase in cultivation and a promise of a much more rapid growth in the immediate future.

The increase in security in western Kansas within the past year and a half is a notable tribute to the discussion, interest, and investigation that has followed the work ordered by Congress. The people of the new Territory of Oklahoma have already found it necessary to consider the need of preparing for a moderate degree of water conservation and distribution. The fertile agricultural area, on which they have so rapidly built a new commonwealth, is liable to the same drought and depression that has elsewhere along the eastern line marred agricultural settlement with variable rainfall and hot winds that desiccate. The able and almost minute report of the geologist for Texas in the artesian and underflow investigation, Prof. Robert T. Hill, as well as evidence given elsewhere in this report, shows a marked increase in activity in cultivation and growth of population throughout the central, western, and northwestern portions of Texas. But the largest result of irrigation enterprise in the opening of a great area yet seen is that which is making so marked a development in eastern New Mexico. The valley of the Pecos and the plateau region of the Raton Mountains have, until within a year or two, been practically unknown to the average American as a part of the common country. What little use has been made of this extensive area during the past twenty years has been confined to a sporadic occupation thereof for the feeding of stock and the raising of sheep.

The irrigation development of the past two years is notable in character, not only because of the extent of the works and the capital invested or of the area opened, but because, in the case of the more northern enterprise—that which is located upon the Raton plateau—there are engineering and agricultural experiments under way, which, if they prove successful, will add vastly to the value and utilization of great table land regions that are now supposed to be adapted only to pastural purposes. The two systems in operation upon the Maxwell Grant, covering an area of 65,000 acres, and supplied from branches of the Canadian and Cimarron rivers—streams whose mountain sources are fed from the vast precipitation of the Sangre de Cristo Range—present in their development the possibility of a great, even vast, increase of the agricultural area of the arid region. The altitude at which successful farming is carried on, the still higher range at which healthy orchards bearing an ample return of fruit in fine condition were seen during the summer of 1891, the remarkable engineering experiments by which with works of a simple and not costly character the mountain supplies are brought out and stored upon the open table land and from such storage distributed to the farm lands under them, all these point to both the possibility and probability of utilizing a very considerable proportion of such higher table lands and plateau region. The experience now being gained will probably encourage experiments and operations in favorable northern latitudes. The Special Agent after his visit to Northern New Mexico and elsewhere, expressed the opinion that the success of the open table land reservoir system illustrated on the Maxwell Grant, in Southeast Colorado, at Nampa under the Boise River in Idaho, and more recently in the conservation of water in the open lagunes which are being appropriated under the Bear Valley system in Southern California, will add from thirty to fifty million more acres to the arable area of the country. Certainly, that portion of the table land or plateau region which will be affected by the success of the Maxwell system will be likely to come under the influence of a development that, bytaking advantage of every opportunity of storage, large or small, and of all available phreatic supplies that may be found, will tend to the establishment in time to come of a mixed arable and pastoral farm settlement. Such a statement may seem quite speculative in character, but to the observer making the same it is based on both comprehensive and minute inquiry, facts, and conclusions, and it enforces on him a remarkable and even early possibility of successful achievement, or at least the decided beginnings of the same.

The north and south lines of the parallelogram of movement and development already indicated, runs on the north, chiefly through Wyoming and the southern portion of Idaho, and further north up the Valley of the Yellowstone and over the Rocky Mountains at Missoula, into the Pacific northwest, east of the Cascade Range. The increase of population has not been large, but steady in character, while the increase in reclamation enterprises is on a decidedly large scale, and the investments made and enterprise shown in construction, point decidedly to an early effort to encourage and direct active settlement. Several great areas are opened up under this northern line. Perhaps the most direct increase of cultivation and the systematizing of necessary works upon the north is to be seen in the Gallitin Valley, Montana, where irrigation has practically been a success for the last twenty-five years. New and extensive areas that will soon invite occupation are to be found in southern Idaho, eastern Washington, and Oregon, as well also in northern and central Montana, east and west of the Rockies. Extensive reclamation works are in progress in that State, but considerable attention must yet be given to organizing administration of the water and occupation of the land.

On the southern line the movement of population is slower. It is naturally somewhat different in character to that which moves upon the northern line, because the climatic conditions of New Mexico and Arizona invite a somewhat different type of population; but the horticultural development and the large promises of return it carries, are building up a very distinct and definite character, cultivation, and settlement therein. The western line of the parallelogram suggested is following northward from the Colorado desert through the great valley regions of California, until it meets and mingles with the movement that along the northern line has already begun to occupy the southern portion of eastern Oregon. The great interior of the region thus defined has felt to a considerable extent, though not generally over its whole area, the same interests and activity, which, under investigation, is shown to be most directly along the lines given.

The progress of irrigation reclamation is concretely indicated in a statistical form by a table that follows. There is but little satisfaction in presenting estimates, but the limited force, with the equally as limited time at command, forbids doing anything else. This claim can be made for the figures annexed, and that is, that they are all reasonable and it is believed well within the facts.

Irrigation areas and artesian wells west of the ninety-seventh meridian.

State and Territory.	Acreage.					Number artesian wells.*
	Under ditch.			Cultivation.		
	1889.	1890.	1891.*	1890.	1891.*	
Arizona	529, 200	643, 450	660, 000	310, 100	315, 000	*a*45
California	3, 294, 000	4, 044, 000	4, 500, 000	3, 444, 000	3, 550, 000	3, 500
Colorado	2, 813, 273	4, 082, 738	4, 200, 900	1, 585, 000	1, 757, 162	4, 500
Idaho	715, 500	1, 181, 500	1, 200, 000	327, 000	330, 000	12
Kansas, west of 97° of longitude	500, 000	860, 010	900, 000	100, 000	120, 000	250
Montana	986, 000	1, 100, 000	1, 250, 000	400, 000	410, 000	36
Nebraska, west of 97° of longitude	50, 000	65, 000	200, 000	10, 000	40, 000	100
Nevada	142, 000	150, 000	150, 000	75, 000	100, 000	76
New Mexico	638, 455	677, 315	700, 000	450, 000	465, 000	10
North Dakota	....	1, 000	2, 500	1, 500	2, 000	*b*670
Oregon, east of Cascades	75, 000	100, 000	125, 000	45, 000	45, 000	6
South Dakota	100, 000	100, 000	100, 000	22, 000	54, 000	*b*950
Texas, west of 97° of longitude	200, 000	340, 000	350, 000	160, 000	160, 000	*c*1, 000
Utah	700, 000	700, 000	735, 226	413, 000	423, 364	*d*2, 524
Washington, east of Cascades	75, 000	150, 000	175, 000	60, 000	75, 000	10
Wyoming	1, 946, 876	*e*2, 172, 781	*e*3, 038, 481	*e*175, 000	*e*180, 000	6
Total	12, 765, 304	16, 367, 794	18, 286, 207	7, 577, 600	8, 026, 526	13, 695

NOTE.—The figures of this table are necessarily estimates, made by the Irrigation Inquiry, but they are all well within the facts. All the wells given come within the definition of "positive" artesian water adopted by this office.

a The first successful artesian well in Arizona was drilled in 1881; the total given was reached by 1888.

b The deep artesian wells in Dakota, now completed, number 105; the shallow flowing or drift wells are estimated at less than 800. The State engineer reports over 100 township wells contracted for and in process of construction, and about 250 more private enterprises are reported. In North Dakota there are 19 deep flowing wells, and about 650 flowing shallow wells in drift deposits in the Red River Basin.

c In Texas, in 1890, about 700 flowing wells, deep and shallow, were reported upon, and at least 300 more have since been bored.

d The Utah total is the statement of the U. S. Census accepted as correct in the Territory, up to July 1, 1890. The number has since been increased sufficiently to warrant the estimate of 2,800. These are all shallow depth, flowing wells, supplied from drift deposits. This is an addition of 276 wells, making the total 13,971.—Statement of Territorial experts.

e From report of State Engineer Mead, 1889–'90, and of Mr. P. L. Naismith, assistant engineer, for 1891, made to this office. The figures given for 1891, as "under ditch," are from the State records; those for 1892 include 856,700 acres as covered by works in process of construction or projection under prior appropriations.

The irrigation developement in Wyoming is as remarkable as that of any portion of the western region. Up to January 1, 1891, the following are the figures:

Total number of ditches	3,050
Total length in miles	5,464
Total capacity in second feet	2,563,900,000
Total acreage under ditch	2,172,781
Total estimated cost at $3.62 per acre	$7,865,467.22

For the year 1891, closing December 31—

There were of applications for ditch appropriation	210
Covering a mileage of	970
Designed to serve (acres)	856,700
At a cost (estimated) of	$3,464,269

It is true that the projected operations of 1891 are as yet mainly in the air, though a considerable proportion of the work needed is under way, and the greater portion will finally be constructed.

Another most notable development is in the matter of storage. Colorado is especially active in that direction. The State engineer's report for the two years from 1888 to 1890, shows the following totals:

Reservoirs recorded in his office up to 1890	354
Ditches on file there 1888; number of	2,679
Estimated and stated mileage of same	10,023.45
Number of ditch appropriation recorded from 1888 to close of 1890	1,380
At an estimate of 4 miles to each ditch, the total will be	5,420

The report for 1886–'88 shows a total of 74 storage reservoirs, most of them smaller than the latter constructions, while a number of them were only intended for stock purposes. The increase in two years has been 280, and if we to allow a filing of one-half more, or 140, for the year 1891, it would increase this class of constructions, more of which are under way, to 494 storage sites. A great many of these, the majority in all probability, belong to the class of plains or open valley storage which has been referred to. The increase in ditches and mileage for the past year will certainly be one-half the total given for two years covered by the State engineer's report, 690 ditch filings, with an estimated length of 2,710 miles. Adding these totals together we shall have for Colorado, at the close of 1891, an estimate

Of reservoir sites and construction	494
Of ditches constructed and under way	3,369
Of mileage, recorded and estimated	18,153
At 300 acres per mile, this will give a total as under "ditch" of	4,445,900

Another step in the conservation of water within this region has been in the passage of the act passed by the last Congress authorizing the President to set aside by proclamation any portion of the public domains as forest reservations as may be desired. It is to be hoped this measure will be so administered as to include the sources of all interstate waters. The need of such reservations will become at once apparent to anyone who will examine a proper map with critical eyes. It will be seen that the controlling power over a continental water supply is held both geographically and hydrographically by the minority in physical area, civic organization, and population. Three States, embraced within the area of the Rocky Mountains, holds the sources of at least 60 per cent of the western waters of the Mississippi system, and at least 90 per cent of all the flowing streams west of the one hundredth meridian. It is a subject of profound interest and one that must command the attention of legislators, state and national.

The deep artesian wells of South Dakota now completed number 105. The shallow flowing wells of the drift area, chiefly found in Miner and Sanborn counties, are not less than 800 in number. According to the State engineer of South Dakota, over 100 public artesian wells have been authorized and contracted for. As many more have filed applications in his office. Some two hundred and fifty private artesian enterprises are reported. There are in North Dakota 19 deep wells reported and about 650 shallow flowing wells, nearly all located in the drift deposits of the Red River basin, in the northeast section of the State. About 150 wells have been added to the number previously reported by the artesian and underflow report of 1890 as located in western Kansas and Nebraska. In the San Luis Valley, Colorado, some two hundred shallow wells have been bored during the past year.

In New Mexico there are now ten or more flowing artesian wells near Springer and at Roswell and Eddy, in the Pecos Valley. Several experiments elsewhere in the Territory are under way. The successful boring of artesian wells in Arizona is of considerable importance and bids fair for future development in this important direction. There is no doubt whatever that Arizona has a large supply of phreatic waters, with at least a negative artesian character—pressure sufficient to rise in the bore, if not to overflow at the surface. In western Texas (west of ninety-seventh degree) there were reported in 1890 about 700 flowing wells. At least 300 have been added to the tally, while the number of bored wells with an ordinary phreatic supply and pressure has more than doubled in the past two years. Up to July 1, 1890, the total (2,524) given in the table for Utah, being the same as reported by the United States Census Office, is accepted as correct. Since that date, however, the increase justifies a present estimate of 2,800 flowing wells in that Territory. The chief fact about recent development is the achieved certainty of a large phreatic supply, which is certain to be reached and utilized to great benefit by means of bored and driven wells. In the Pacific Northwest there has been some notable well development, and in California an increased irrigation supply is being obtained from that source. Other development in the direction of drainage supplies is found in the increased number of underflow enterprises, such as bedrock dams, drift tunnels, gravel-bed gravity or pumping, the opening of springs, the lifting of water, and the increase by sub-canals of underflow supply. Altogether, the activity and development in reclamation works has been very notable.

THE ART OF IRRIGATION AND AMERICAN SUCCESS.

The art of irrigation, probably originating in Southern Asia, has been known from remotest historic times. The Chinese, the primitive inhabitants of India and Persia, those contemporary with the kingdoms of Babylon and Nineveh, and who then inhabited the country lying between the Euphrates and Tigris, and finally the Egyptians, all appear to have made extensive use of irrigation. The Romans borrowed the system from the East, and transported it into Italy and the south of France. Lastly, the Arabs, also coming from the West, introduced it into Spain. Since then, however, the art of irrigation has remained almost in the same condition as at that time, and in spite of the unprecedented spread of modern civilization and in spite of the indisputable progress made of late in agriculture, but a small amount of territory, comparatively, has been reclaimed by irrigation. The largest progress of area in later years has been made in British India, where about 30,000,000 acres have been either newly reclaimed or made secure to the cultivator by the construction of new supply works. The larger proportion of this great work has been done within the last thirty years, and one-half of it at least within the past fifteen years. The amount invested exceeds $150,000,000, and the profit thereon is large though obtained from indirect methods, such as land revenue and the increase for industry found in the security and peace of the empire. A considerable proportion of the works have, however, yielded a fair per cent of profit for several years on the large capital invested. In the northwest provinces, for example, where the administration has been able to concern itself with some simple questions, though of great magnitude, such as the reclamation of new lands, the restoration on purely engineering grounds of old works, the renewal and settlement of land workers or ryots, and the framing and execution of simple laws and regulations based on old customs and rules, the direct profit resulting on capital invested has been sufficient to satisfy the most exacting of investors.

The progress of the United States is next in order. In the past seven years the actual area of reclamation by irrigation cultivation has increased from about 5,000,000 acres to at least 8,500,000 acres, or, according to the table accompanying this report, 8,026,526 acres. There are small areas scattered throughout the region beyond the one hundredth meridian west from Greenwich, of which no reports have been made, sufficient in total amount to increase the figures to over 8,500,000 acres. But greater activity than this addition of 3,500,000 acres to the area of cultivation is seen in the growth of important hydraulic works. "Under ditch" this office reports for 1891 an estimated area of 18,286,207 acres. The largest proportion of this great addition to the cultivatable area will be made available for use within the next year; and by the opening of the World's Columbian Exposition, the United States may anticipate the cultivation by means of irrigation of at least 17,000,000 acres of land that within the past decade have been declared by learned authority as wholly irreclaimable, worthless for agriculture, useless for tree planting, and hardly fit for even the grazing of scraggy sheep and the broad-horned steer. Under projected works or partially constructed, nearly 5,000,000 acres may be added, making in all as now reclaimed or in process of reclamation not less than 25,000,000 acres.

THE WORK OF AMERICAN ENGINEERS.

The map prepared from data furnished by the special agent in charge of the irrigation inquiry clearly illustrates the mode of settlement and occupation, and indicates also what must be the principles controlling the work of consulting engineers. Some sharp criticisms of the hydraulic and construction conceptions and execution of American engineers engaged in irrigation work are finding their way into the great and general discussion now in progress. A large amount of this criticism is pertinent and well directed; but very much proceeds from engineers trained in other lands, or from their younger admirers, who endeavor to imitate or mold after formulas and systems adapted to other conditions. There is doubtless considerable truth in Mr. Cope Whitehouse's criticism that "we have lots to learn in western America before we can talk irrigation." That may be unquestionably true, but there is good reason for denying the correctness of the further remark, attributed to the same eminent engineer, that "with scant exceptions" we are "below the level even of the minor modern constructions to be found among those Oriental nations whom the American engineer has been taught to despise." Putting aside the self-contradictory segment of this dicta it must be said that a large proportion of the important irrigation works constructed in our Western States during the past six or eight years are the equals of even the Anglo Indian works, after taking out such great enterprises as the Upper and Lower Ganges canals, those of the Jumma, and a few others. There are American works that will stand comparison with any in the world not constructed of masonry. Among such must be considered the very notable system known as the Bear Lake and River irrigation works in southeast Idaho and northern Utah; the Idaho and the Nampa canals in the Boisé Valley, Idaho; the splendid constructions that are progressing in the Modesto and Turlock, and the Colusa irrigation district of California; the very clever work done on the Maxwell grant in eastern New Mexico, where in both cases there is a large degree of engineering adaptability shown in devising plans suitable for climatic and topographic conditions. The great activity now displayed in Colorado with regard to the storage of water is giving play to skillful use of engineering and expert knowledge and capacity. There is not to be found elsewhere the equals in capacity and economy of service, in results obtained, in methods of conservation, and in modes of distribution, especially in the latter direction of some of the systems now in vogue in southern California. There is no more bold engineering than that which has already stood the test of time and the strain of most unusual stormy precipitation, in the Sweetwater and the Bear Valley reservoirs and dams. They clearly point the way to the large systems of water storage that are, as rapidly as needed, coming into use. And the new works, such as the Tuolumne, the Hemet, and others, that are under way show a careful taking advantage of past experience. The methods of distribution, the materials employed, and the skill displayed in the work accomplished by the service at Riverside, Ontario, Redlands, and the Alessandro and Perris districts, are almost if not wholly unequalled in the history of irrigation engineering, ancient and modern, and their projectors, engineers, constructors, and administrators, are all Americans. Only one important California work has been devised by an engineer trained in the great Anglo-Indian school of irrigation works, and it has received very sharp criticism. The able engineers who have officially examined our systems on behalf of the Australian colonies of New South Wales and Victoria, as well as the more recently, the representative of the Russian Government, whose duties relate to the plans for irrigating the Asiatic oases now in possession of Russia, do not appear to share in the critical objections under consideration. The transfer to Victoria and South Australia of the energies and organizing abilities of the irrigation experts who made the settlement of Ontario, southern California, an era in fruit culture and economical water service, is a tribute to American capacity in that direction, which engineer critics can not afford to ignore. This reference is made not because the unfavorable allusions are undesirable as a spur to better efforts, but because their expression represents a point of view unfriendly to the progress of irrigation on lines already well defined. When it is really based upon a genuine desire to see security in construction combined with comprehensiveness in plans, it is too closely identified with the type of intellect and training which can only work to its best advantage upon the method of the paleontologist, who from one fossil bone can reconstruct the full skeleton of an unknown mammal.

IRRIGATION LEGISLATION.

During the year 1891 great activity and interest has been manifested in legislation, as well as in judicial decisions relating to water supply and its management within the States and Territories of the arid region. A brief review of the salient facts in connection with these is given.

In California the district irrigation system has been pressed steadily to a slowly growing success in spite of the fact that certain interests in various districts have made a strong legal fight against the laws and their operation. So powerful, however, is the feeling in that State in favor of this system that both the supreme and district courts uniformly advance all cases arising under them. The majority of such cases heretofore have been of a friendly character, intended to obtain decisions upon amicable presentations of disputed points of interpretation. During the year 1891 a number of cases have, however, arisen in deliberate hostility to the effective working of the laws and the constitutionality of their provisions. The reason of this feeling is not far to find. The effects of district irrigation in southern California and in the San Joaquin Valley have been so marked in both the peace produced and the profits thereof, that it has stimulated activity in the northern and more central portions of the great valleys of the San Joaquin and Sacramento. The organizations of districts projected, like the West Side and Sunset in Fresno County, the Madera, the Turlock, and Modesto, in Stanislaus County, and the three large districts in Colusa County have aroused feelings of hostility against the system on the part of many engaged in very extensive wheat culture or in the holding of lands for speculative purposes. To those acquainted with the conditions of wheat ranching in the portions of California mentioned it will not be a surprise that legal resistance should be made against well directed efforts under the district law of the small landowners and farmers to bring about better cultivation and the settlement of a larger population. They want more population and industry to bear the burdens of taxation and bring about improvements. Recently the State supreme court directed a retrial of a case in which the Madera district is involved. The constitutionality of the original Wright law was pressed by the parties against the district. This, it is reported, was more directly involved in the Madera case than in any that has appeared before the court, but the full bench threw out all such pleas and simply directed a re-trial upon an error made by the lower court in hearing some testimony not properly before it. It seems probable that with this conclusion there will be a cessation of attempts to legally obstructing the progress of the irrigation district system in California.

In Nevada the present district system has been applied and limited to the storage of water, leaving to irrigated communities themselves the task of managing and arranging with prior appropriators the community work or plan of distribution through the amicable purchase or condemnation of individual rights. One district has been fully organized under the law and embraces the Truckee Basin, with Lake Donner as a storage reservoir. Another one will probably soon be organized in the Humboldt Valley. In Oregon, at the last legislative session, elaborate provisions of law were made for the supervision and distribution of water for irrigation purposes. These provisions were of such a character as to lead almost inevitably to the enactment at the next session of a district system for the eastern part of the State.

In Washington, under an act passed at the last session of the State legislature, a district system has been organized. Several water supply areas have been formed into irrigation districts. Two of these are in the neighborhood of Ellensburg. A section of which North Yakima is the chief town has also been formed into a district. Others are reported, but no details have reached this office. The districts in Kittitass County it is claimed have proved a marked success, united the efforts of the people toward the improvement of their water supply, and aided in stopping neighborhood litigation.

The first legislature of the State of Idaho, in session from January to March, 1891, passed a memorial to Congress, which, as it represents very clearly the feeling in favor of a change in the national public land system and presents the argument therefor in a conservative manner, as a matter of information and as a part of the general record, is herewith embodied:

To the Senate and House of Representatives
of the United States in Congress assembled:

Your memorialists, the first legislature of the State of Idaho, would most respectfully represent:

That the State of Idaho lies wholly within the arid domain, and that agriculture is dependent upon irrigation. The reclamation and settlement of the agricultural lands must be accomplished therefore under different conditions from those confronting the pioneers in the humid portions of this country. The present land system is the outgrowth of the experience of humid districts, and is wholly unsuited to the conditions which prevail in this State, and as a result interposes serious obstacles to the rapid and prosperous utilization of our agricultural resources and the making of homes by those who are ready and willing to take part in reclaiming the desert.

Your memorialists would also respectfully represent that the most effective remedy for these evils, and the measure which promises the most beneficial results, not only to this State, but to the whole country, would be for Congress to donate to this State all the agricultural and grazing lands within its borders, under such restrictions as would safely and perpetually secure their utilization by actual settlers and cultivators of the land donated, and would respectfully offer the following as among the reasons for asking for such control and as justifying such donation:

That the reclamation of the agricultural lands imposes upon the settlers engaged in the work and upon the State government obligations and expenses not incurred in the humid portions of the country. Not only must ditches be constructed and the lands be prepared for the application of water before there is any return to the farmer, but with the multiplication of these works it becomes necessary for the State to exercise a supervision over them in order that those entitled to the use of the public waters may receive it. The expense of such supervision is of necessity heavy. In Idaho there are 2,000 ditches diverting the waters of over 500 streams. The examination of these claims, the determination of the priority and the subsequent division of the waters among the various claimants gives rise to problems which require both ability and experience on the part of those charged with their solution and requires the employment by the State of a large number of officers.

Thus far the Territory has borne the entire expense of the investigation of our agricultural resources and of the supervision of our public waters, and by the action of Congress granting the State the ownership of all the waters within its borders the expense and responsibility of such supervision must continue to be borne. The efficiency of this supervision is greatly impaired by the inability of the State to assist in any way in the reclamation and settlement of the desirable lands or to restrict the diversion of water on the less desirable. In this connection it must be remembered that the lands susceptible of irrigation is largely in excess of the water to serve them, and that agricultural values inhere in the water rather than in the land. Such selection should therefore be made as will secure the use of the water on the best lands, since they vary greatly in value and the quantity of water required. With no supervision the water may be so diverted that the quantity required for irrigation of one acre would suffice for the reclamation of two, three, or four acres of land in more favorable locations, but so long as this matter is left wholly to individual ability and inclination, so long will the public interest be lost sight of and wasteful and improper diversions be made.

Our experience during the past five years has shown the evils growing out of the control of the land being under one authority and the water under another. If the late Territory of Idaho could during the past ten years have controlled the disposal of the irrigable lands within its borders, it could, while disposing of it to actual settlers only, have afforded such protection to canal companies as would have given our agriculture four times its present importance and more than doubled our population. The most extensive and valuable bodies of irrigable lands in the State, those bordering our principal rivers, more particularly the Snake River, are untouched, because the experience in constructing canals and the time required for their completion places the work beyond the reach of individual enterprise and effort, and the general land laws have made colony or corporate enterprises too hazardous to be undertaken. The local government could do nothing to aid the work, both from lack of means and want of proper control. Another evil of the present condition of affairs is the tendency toward a separation of water rights and land titles. If the State controlled the lands it would be possible to connect water rights with land titles of all irrigable lands. That this is desirable is admitted by all familiar with the subject. It is both an aid in preventing monopolies in water by companies and securing its more economical use by farmers.

The importance of the pastoral interests in this State makes it desirable that provision be made for the utilization of the grazing land in connection with the contiguous irrigable areas. These lands comprise a large part of territorial extent. They can never be made the self-supporting habitation of man, but furnish a valuable complement to the lands reclaimed—the first furnishing the summer's and the latter the winter's food supply. None of the present land laws make adequate provision for securing possession or management of these lands, and some further legislation is needed to meet the requirements of our prospective development and increased population. We believe, however, that it is impossible for Congress to pass a general law which will operate with equal justice and success on the arid belt as a whole. The conditions differ in different sections, as do our water laws. Idaho differs from Utah, and Arizona from Montana and Wyoming. The people of each section are the best calculated to determine the system best suited to their needs, and should be given the means of carrying it into effect.

The results already achieved are a sufficient guaranty of what can be accomplished under more favorable conditions. Under the territorial laws $10,000,000 was invested in irrigation works and over 1,000,000 acres of land reclaimed thereby. Not only has the value of the land been enhanced thereby from ten to one hundred fold, but its productive capacity has been correspondingly augmented. Such results are of interest and value to the whole nation, and we believe entitle the State to generous recognition. The provisions of the State constitution require the inauguration of the most systematic and complete supervision of the public waters yet undertaken by any Commonwealth in this country.

It is only, however, by uniting the control of both water and lands under one authority that our irrigation system can have the fullest measure of stability and success. We believe that the control of this subject can wisely and safely be intrusted to the State, since the practical knowledge of irrigation in this country is almost wholly confined to those engaged in the work. By endowing the State with means and placing upon it the responsibility for the development of our resources, a great impulse will be given to the diffusion of intelligence on the subject and to local pride in the character of our irrigation works. It will put the solution of this problem in the hands of the people best informed and most interested in its success.

An elaborate bill providing for the appropriation and distribution of water, the condemnation of land for canals, ditches, and conduits, empowering county commissioners and district courts to establish a maximum rate for the use of water, and providing also for the adjudication of right and priorities in appropriating, diverting, carrying, or storing water for beneficial purposes, was passed by the legislature. The governor, under date of March 21, returned the bill to the secretary of state with his veto. This document is one of decided interest, and so clearly gives the objections urged against certain forms of water management and administration that it will be read with interest. It is as follows:

The general scope of this bill, as is shown by its title, is a very broad one. It aims to regulate one of the leading (if not the leading) industries of the State. A large percentage of our arable lands are properly termed arid, and without water artificially introduced will be valueless for centuries to come, as they have been for centuries past. The land exists in place. It can not be brought to the water—the water must be brought to the land. Only a small amount of our arid land is susceptible of irrigation by small and comparatively inexpensive canals, which are or may be constructed by associations of farmers, who divide the water among themselves and are quite independent of any statutory system of distribution and regulation. But by far the largest portion of the arid land must be irrigated by canals of great size and length, involving the expenditure of great sums of money and much time in their construction. These enterprises are the ones mainly affected by the provisions of this bill. It is true, the consumers of water are also intended to be protected in their constitutional and equitable rights, and though not numerous at present, it is fairly to be presumed will become very numerous, indeed, in the near future.

But this can only happen when water is brought on or in the vicinity of the land to be irrigated. Up to the present no complaint has reached me that the rights and privileges of this class of our citizens have been infringed or threatened. It is one of the possibilities only of a more or less distant future that these rights may be infringed. In the meantime the possibility of rigorous and perhaps prohibitory restriction upon the sale of water tends to discourage the completion of canals already under way, and prevents the formation of new enterprises, of which our State now stands so much in need. These considerations lead me to the conclusion that so much power ought not to be conferred upon a practically irresponsible body of men as is conferred upon the county commissioners by this act. The law is premature. The danger has not arisen. I have examined the present law. It contains the fundamental principles that underlie a good irrigation scheme, and when the time for elaboration of details arrives I am fully convinced that a legislature with wisdom and discretion equal to the task will also appear in view.

Respectfully,

NORMAN B. WILLEY,
Governor.

In Arizona, during 1891, a constitutional convention met at Phœnix, the capital of the Territory. The most striking discussion during its session was over the article on water rights. Propositions to the number of six were introduced. They all united in declaring that the natural waters of the proposed State belonged to the people, were the property of the State, or were held by the legislature thereof for the use and benefit of the public. Riparian rights were denied by all. The legislature was to be given power to supervise and control the distribution of water. The two points at issue were, first, whether by the terms of the article the natural waters of the State should be declared to be the property of the public, held by the legislature in trust for their benefit, or the "the property of the State," the mode and manner of acquiring and exercising which should be subject to legislative control; second, whether or no irrigation districts should be formed.

The following article was adopted in open convention September 29, 1891, as the certificate of the secretary of the convention, H. C. Barnard, testifies:

WATER AND WATER RIGHTS.

SEC. 1. All natural streams and lakes within the boundaries of this State, capable of being used for the purposes of navigation or irrigation, are hereby declared to be the property of the State.

SEC. 2. The common law doctrine of riparian water rights shall never be applied in this State, nor shall the right to use water heretofore lawfully appropriated to beneficial uses ever be denied.

SEC. 3. The right of the people to appropriate and use the unappropriated waters of this State for beneficial purposes shall never be denied; priority of appropriation shall give the better right.

SEC. 4. The right of individuals or corporations to construct reservoirs and impound and appropriate the surplus and flood waters in this State, for sale, rental, domestic, stock, or any beneficial purpose, shall never be denied. The first locator of a reservoir right shall have priority. A failure to construct reservoirs and canals within a reasonable time after location, and a failure to use reasonable diligence to maintain the same so as to supply water, shall be held to work a forfeiture of such rights.

SEC. 5. Every appropriator of water shall use the same reasonably and economically.

SEC. 6. The mode and manner of acquiring and exercising all of said rights shall be subject to legislative control.

AMENDMENT BY COMMITTEE.

SEC. 7. The legislature shall have power to authorize the organization of irrigation districts, and the creation of a debt, for the construction or purchase of reservoirs, dams, canals and ditches, and other appliances required to supply water to lands in said districts. But such debt, principal, and interest shall subject only the lands benefited or reclaimed to taxation to pay the same—

SEC.—. The legislature shall pass laws requiring the owner or owners of every ditch or canal from which water is rented or sold to other parties, to use reasonable diligence in keeping such ditch or canal in such condition and repair as to supply the water required.

The constitution, with this article in it, was ratified by a majority of 3,000 at an election held on the first Tuesday in December, 1891. The discussion in the press and before the people was quite exhaustive, it being charged that, by the article adopted by the convention and popular vote, to the State as a corporate body was given the ownership of the natural waters; that the legislature was empowered to dispose of them and to permit their sale or rental for "beneficial purposes;" that it had no power to prevent access to any body of natural water by any corporation or parties seeking their appropriation for sale and profit; and that said provisions were contrary to the principles found in Spanish and Mexican law, upon which the territorial code had been founded, and the provisions were altogether at variance with the general policy of States like Colorado, which makes water natural wealth and the property of the public, while providing that the legislature shall only be the trustee and conserver, and not the owner or seller thereof. The irrigating ranchmen and farmers of Arizona took a contrary view to these criticisms, while the district provision met with general favor on both sides.

The State legislature of Kansas passed, at its last session, 1891, an elaborate code of legal regulations for the government and distribution of water supply within the semiarid portion of that State. It is probably the most direct, simple, and even drastic system of State and municipal control and supervision, which has yet been legislatively adopted. It provides for the organization of municipal irrigation districts with power to issue bonds for works not to exceed in amount $1 per acre of the area embraced. It also provided for tribunals to settle water disputes and contains other provisions of importance. One district in Finney County, embracing Garden City and adjacent portions of the Arkansas Valley, has already been organized. This bill was framed and submitted to the legislature by Judge J. W. Gregory, of Garden City, who has served the Department in the artesian and underflow investigation. Its main features as drafted by him were adopted.

The operations under the Melville irrigation act in South Dakota bid fair to prove as useful to that State in its degree as the Wright code of laws has in California. It provides that upon petition of at least twenty property owners within a township, the State irrigation engineer shall examine the township for sites for artesian wells. If the engineer approves, the township may issue bonds to pay the cost of constructing not more than nine 6 inch or sixteen 4-inch wells, located by the engineer with a view to their success as wells and their availability for irrigating the lands of the township.

During the year 1891 State Irrigation Engineer J. H. Baldwin located one hundred and fifty well sites, and the number may be increased before his official report is made to the State legislature. The limitation of the townships to the issue of but 5 per cent of their assessed valuation in the matter of artesian-well bonds has given a market stability, which, combined with the assured success of irrigation by means of artesian water, has made this legislation a success.

During the year the State legislature of Colorado adopted laws which were approved by the governor, providing for the encouragement of water storage by means of reservoirs. These methods of storage are multiplying very rapidly, and the legislation proposed seeks to define the legal methods by which the people owning them may be able to use the same without infringing upon the rights of others. Another bill was introduced to define the phrase "water for domestic purposes," as used in the State constitution. This is a subject very much in controversy in that State. Under the bill introduced it was provided that the phrase shall not be so interpreted as to include water for the irrigation of land or plants in any manner or to any extent whatever. Water intended only for domestic purposes is not to be carried for irrigation ditches or conduits, where the loss by seepage, breakage, or evaporation exceeds 2 per cent of the water so carried. Whether this bill became law the office is not informed. Two decisions have recently been made by a district judge, in which the old irrigation settlements of Greeley and neighborhood are greatly interested.

This case has been decided by the judge in favor of the landowner on which an irrigation pump had been operated. It was charged that the water lifted by the pump was the product of seepage from a neighboring ditch. The ditch, however, was not a party to the suit. The persons suing were appropriators of water from a small creek on the other side of the pumped land from the ditch. It was alleged that the ditch seepage had increased the flow of the creek and that upon such increased flow the appropriation in 1886 had been made. When the pumps were in operation upon the land lying between the creek and the ditch the allegation is that the flow almost ceased in the creek. Action was brought to enjoin the further use of the pumps. The judge's instructions were in substance as follows: That water percolating beneath the soil (in no well defined channel) belongs to the owner of the land and he is privileged to use the same as he thinks best. This is the first time that the question has arisen in Colorado and, so far as knowledge now goes, in any of the States requiring irrigation for reclamation purposes. It is quite probable that in Colorado the decision, if sustained by the Supreme Court, will give great impulse to the use of pumps in lifting the gravel-drainage and other phreatic waters. A clause in the irrigation laws of that State, conveys to the man who will develop or bring to the surface of his own land all the water which he may find underneath the same. This much is certain, that, in the interpretation given by the judge and sustained by the jury, the application will most certainly be at variance with the codes and practices of older and more ancient irrigation communities. The general principle of Spanish, Moorish, Indian, and Asiatic law on this subject is, that underground waters developed by a land owner are the property of that person, subject to the condition that the water rights of other persons are not injured thereby. It is quite within the power of persons using pumps to place the same in such close contact with a reservoir or ditch, as actually to drain the waters thereof. A clearer comprehension of the equities underlying such a question as this may soon produce a modification of the decision given.

Another decision by the same court embodies the principle embraced in the contention that a public irrigation canal is a common carrier. It also embodies the conception that the beneficial uses to which water is to be applied must not be hindered or prevented by the action of the canal companies. The plaintiffs in the suit were the owners of a certain reservoir constructed by themselves as farmers. They were also the owners of certain or all of the water rights in a connected ditch. During the last summer their crops being in danger, they desired to run water from the reservoir through the ditch, but were refused by the parties owning the same. An order was given in court granting the right to run the reservoir water through the said canal. An injunction was obtained in a Denver court forbidding this action. This was afterwards dissolved by the same judge. Suit was then entered in the Greeley court, and damages to the extent of $1,200 were obtained. It is alleged that the exercise of this power would interfere with the duties of the ditch as a common carrier, as all head gates along the route would have to be shut down while the water was running. The probability is that this objection was a legal fiction in the case under consideration, as it is understood that the plaintiffs were all the patrons of the ditch in question, but the presentation of such points show the importance of the issues that arise and the legal principles involved. The courts in Colorado are especially involved and loaded with cases connected with irrigation and water conservation and distribution. More and more the necessity will arise for simplifying legal enactments and placing the control of water and works nearer to and more directly in the hands of the people affected by and interested in them.

The following dates and titles refer to the irrigation legislation of the past year in the States and Territories named:

[*California.*—(State Laws, pp. 46, 127, 128, 211, 229, 247) March 1, 20, 31, 1891.]

Regulation—Election of boards of directors of irrigation districts.
Assessments for improvements, irrigation districts.
Board of railroad commissioners to have same powers in relation to irrigation companies as in relation to railroad companies.
Reclamation of lands—Powers of trustees of districts.
Reclamation of districts, unpaid assessments payable in installments.
Organization and government of levee districts, to confine innavigable running streams to fixed channels.
Land and water corporations may divide property among stockholders.

[*Colorado.*—(S. L., pp. 96, 97, 385, 402) March 19; April 1, 2, 1891.]

Reservoirs—Construction by ditch companies.
Ditch and reservoir companies may extend term of incorporation.
Water appropriated for domestic purposes shall not be used for irrigation.
Water rights and lands—towns and cities may purchase.

[*Kansas.*—(S. L., p. 133) March 10, 1891.]

Creation of irrigation districts.
Diversion and appropriation of water for industrial uses.
Rate of charges for water purchased from irrigation companies.
Disposal of seepage waters.
Artesian wells—regulation.

[*Montana.*—(S. L., p. 295) March 6, 1891.]

Mode of obtaining right of way.

[*New Mexico.*—(Territorial Laws, pp. 54, 71) February 24, 26, 1891.]

Water—Appropriation for ditches, canals, or feeders of reservoirs. Filing statement of work necessary to secure priority of right.
County commissioners to furnish tools, work to be done by citizens.

[*Nevada.*—(S. L., p. 92) March 23, 1891.]

Irrigation districts, organization and government.

[*North Dakota.*—(S. L., pp. 33, 34, 75) March 6, 7, 11, 1891.]

Irrigation, formation of districts, regulation.
Creating office of State superintendent of irrigation and forestry—duties.
Sinking by townships for public purposes, issue of bonds therefor.
To encourage construction by private parties and corporations.

[*Oregon.*—(S. L., pp. 52, 74) February 18, 20, 1891.]

Appropriation of water for irrigation and other purposes.
Irrigating ditches.
Punishment for obstructing streams.

[*Washington.*—(S. L., pp. 60, 142) March 2, 9, 1891.]

Appropriation of water for irrigation, mining, manufacturing, or public water works.
Cutting or breaking of dikes or dams.

[*Wyoming.*—(S. L., pp. 8, 88) December 22, 1890; January 10, 1891.]

Water districts—Constitution and government of.
Water commissioners—Appointment and duties of.
Ditch and water companies may issue bonds or mortgage property.

MUNICIPAL CONTROL OF IRRIGATION WATER AND WORKS.

The irrigation districts of California still continue to hold, in the discussion of administrative organization methods, the largest place. The following table, corrected up to November, 1891, will be of value in this connection. It gives a list of the fully organized districts (now thirty-two in number), their location, the names and post-office addresses of the secretaries, the acreage embraced in each district, the amount of bonds voted and sold, and the amount per acre for which the irrigator will be liable in each instance.

Irrigation districts in California, 1891.

Name of district.	County.	Secretary.	Address.	No. of acres.	Confirmed.	Bonds voted.	Bonds sold.	Bonds per acre.
Alessandro	San Bernandino	George H. Kelsey	Moreno, Cal	25, 500	Yes.	$765, 000	765, 000	$30. 00
Citrus Belt	do	C. C. Woodroof	Colton, Cal	11, 700	Yes.	800, 000	800, 000	68. 37
East Riverside	do	J. A. Vanarsdale	do	3, 600	Yes.	250, 000	100, 000	83. 33
Grapeland	do	E. T. Myers	Grapeland, Cal	10, 787	Yes.	200, 000	None.	18. 54
Rialto	do	Devillo Robinson	Colton, Cal	7, 200	Yes.	500, 000	500, 000	69. 44
Box Spring	do			41, 000	No.	Not st'd.	Not st'd.	
Elsinore	San Diego	D. F. Pierce	Elsinore, Cal	11, 300	Yes.	452, 000	(*a*)	49. 88
Linda Vista	do			42, 000	No.	None.	None.	
Jamacha	do			22, 000	Yes.	Not st'd.	*b*25, 000	
Otay	do			60, 000	No.	None.	None.	
San Marcos	do			40, 000	Yes.	350, 000	*c*350, 000	9. 45
Alessandro	do			25, 000	Yes.	765, 000	*a*765, 000	30. 65
Escondido	do	A. J. Werden	Escondido, Cal	12, 800	Yes.	450, 000	(*a*)	35, 12
Fallbrook	do	G. A. Scott	Fallbrook, Cal	12, 000	No.	400, 000	(*a*)	
Murrieta	do	J. C. Mason	Murrieta, Cal	15, 600	No.	None.	None.	33. 33
Perris	do	H. A. Plimpton	Perris, Cal	22, 800	Yes.	442, 000	*a*252, 000	19. 48
San Jacinto and Pleasant Valley	do		Winchester, Cal	19, 700	No.	None.	None.	
Spring Valley	do			22, 000	No.	None.	None.	
Big Rock Creek	Los Angeles	L. C. Tilghman	Llano, Cal	40, 000	Yes.	400, 000	400, 000	10. 00
Pomona Orange Belt	do	F. P. Firey	Pomona, Cal	4, 500	*Yes.	200, 000	None.	44. 44
Palmdale	do				No.			
Vineland	do	I. N. Rhodes	Vineland, Cal	4, 500	No.	50, 000	50, 000	11. 11
Santa Gertrudes	do	F. McCarie	Santa Fé Springs	2, 600	No.	None.	None.	
Anaheim	Orange	B. V. Garwood	Anaheim, Cal	32, 500	† Yes.	600, 000	200, 000	18. 46
Orland South Side	Colusa	T. H. Dawson	Orland, Cal	25, 000	Yes.	None.	None.	
Central	do	R. DeLappe	Maxwell, Cal	156, 550	Yes.	750, 000	480, 000	4. 78
Kraft	do	J. W. Rogers	Orland, Cal	13, 500	Yes.	80, 000	None.	5. 93
Colusa	do			100, 000	No.	600, 000	None.	6. 00
Tulare	Tulare	E. Oakford	Tulare, Cal	36, 700	Yes.	590, 000	150, 000	13. 61
Tule River	do			18, 000	No.	Not st'd.	Not st'd.	
Poso	Kern	J. E. Anderson	Spottiswood, Cal	40, 000	Yes.	500, 000	250, 000	12. 50
Kern and Tulare	Kern and Tulare	J. O. Sidener	Delano, Cal	84, 335	‡Yes.	700, 000	350, 000	8. 60
Madera	Fresno	E. H. Cox	Madera, Cal	305, 000	Yes.	850, 000	None.	2. 78
Alta	Fresno and Tulare	George H. Weaver	Dinuba, Cal	129, 927	Yes.	675, 000	416, 000	5. 19
Sunset	do	M. McWhorter	Selma, Cal	363, 400	No.	2, 000, 000	None.	5. 50
Selma	do	W. L. Chappell	do	271, 000	No.	None.	None.	
Modesto	Stanislaus	C. S. Abbott	Modesto, Cal	81, 500	Yes.	800, 000	142, 000	9. 81
Turlock	Stanislaus and Merced	R. M. Williams	Ceres, Cal	176, 210	Yes.	600, 000	422, 500	3. 40
Browns Valley	Yuba	John McFarlane	Browns Valley	43, 000	No.	100, 000	100, 000	2. 56
Happy Valley	Shasta			18, 000	No.	None.	None.	
Total				2, 412, 215		14, 787, 000	652, 500	‡20. 80

* Confirmation of bonds denied.

† Bond issue declared illegal.

‡ Average cost per acre on 29 districts that are among the most costly in California. This figure represents, however, a 20 years purchase.

a These districts are now being, or will be furnished water from the Bear Valley system of reservoirs.

b Works of a private corporation have been purchased.

c Negotiating with Eastern construction company for sale of bonds.

It will be observed that twenty-four of these organized districts are located in the four southern counties; that one is in Fresno County, two in Tulare; three jointly in that county and Tulare; one in Kern, and one in Kern and Tulare; with one, the Turlock, in Stanislaus County, and one in Merced County (the Modesto); the San Joaquin Valley has 11 of these organizations. Colusa County, in the Sacramento Valley, northern California, has three districts, and Yuba, a lower Sacramento county, has the remaining one. Up to the date of this table, twenty-four districts have been confirmed by the courts. The bonds of only one district have been declared illegal. Thirteen of the thirty-nine named in the table are still in process of organization. The voters of the Sunset district have rejected the proposition for an issue of bonds.

The State Association of Irrigation Districts have succeeded in securing the favorable support of San Francisco banks in the work of negotiating the bonds of the several districts. The State Board of Trade asked for a special investigation of the district system by the Department, and the Irrigation Congress which assembled at Salt Lake City in September, 1891, also indorsed the system. Under a later date than the table given, from report made at a meeting of the State Association, it is learned that the Vineland district, Los Angeles County, had successfully disposed of $50,000 in bonds. The district is small, containing only 4,500 acres, and is devoted wholly to fruit growing. A tunnel of 300 feet has been made and 15 miles of vitrified clay pipe has been laid. The Anaheim district has sold its bonds to the amount of $200,000. In the orange district, not given in the table, the water needed has been bought with bonds at par. East Riverside (embracing the Gage wells and canal system) has been successfully organized and all the bonds are sold or taken in exchange for a water supply. No other particulars received. The Browns Valley district, Yuba County, has sold $120,000 of its bonds, the full issue. Pasadena, the well-known fruit-growing community of Los Angeles, has also decided to form a district organization, and steps to that end have been taken. The consensus of opinion throughout California is strongly favorable to this policy. Engineer Grunsky, of San Francisco, expresses this opinion when he says in a paper sent to this office, that—

> The advantage of vesting ownership and control of canals upon which landowners must rely for their supply of irrigation water in the landowners or rather in the land itself, received a proper recognition when the law authorizing the formation of irrigation districts was passed four years ago. District after district has been formed under this law until there are now about thirty duly organized in this State. Some of these districts by reason of the purchase of canals already in successful operation are now gradually developing sets of rules and regulations for the distribution and use of water, others are rapidly carrying their works forward to completion, but most of them have barely commenced construction of works.

As already stated the California method has made its way into other States. There are three districts formed in Washington, and one in Kansas, under recent legislation of those States. In South Dakota over one hundred artesian wells districts (township) have been formed. There is some question as to the bonds under the Dakota law, which however will probably be cured by the next State legislature.

OPPOSITION TO THE SYSTEM.

The progress of the California irrigation district system is a matter which materially concerns all of the communities interested in the management of water for the purpose of cultivating the soil. A considerable controversy has arisen, and various charges have been made as to the failure of certain districts to furnish a proper supply to their resident irrigators, and also intimating extravagance and corruption in the management of other districts. This office, in consideration of the policy involved in the progress of the California system, endeavored to ascertain the truth of the criticism of the charges made. Without partisanship it is easy to perceive that well-established canal and irrigation companies having large areas prosperous in condition tributary to their systems would naturally be opposed to any change which would destroy their organization. The opposition this would make must of necessity be powerful when the company interests is strengthened by the objection of the cultivators under their ditches to any change in the system. In the great raisin-growing region about Fresno this feeling on the part of canal owners and irrigators is very marked. Outside of the vineyard section there are in that county great tracts of land owned by single individuals or combinations of persons and held largely uncultivated for the market rise. A natural consequence of such a condition is the efforts of the more intelligent irrigator, who may own but a small farm, to secure the advantages which association produces under the Wright district system. Following the lines of this interesting movement a controversy relating to the Selma irrigation district was noticed as proceeding in the press. Correspondence had with leading men shows that the proposed district is now irrigated by a system of ditches belonging to a private corporation. The issue of bonds for the purchase or construction of works was decided at a district election, and a majority of 119 votes were cast against the proposition. It is alleged on the one hand that the corporation actively worked to secure the defeat; on the other hand it is asserted that the majority of those voting were content with the service furnished by the private company. All sorts of statements were made during the canvass. The Alta irrigation district, on the other side of Kings River from Selma, is one of the oldest formed under the Wright code. Against its administration accusations were made that the cost of irrigation was $5.75 per acre for the last season and that only 10,750 acres were watered. Mr. C. C. Wright, author of the laws and attorney for the district, in reply to a letter, pronounces the statements to be without foundation. Mr. Wright says:

> When the Alta district was formed there ran through it a large canal (then the largest in the State), and as its location was of the most favorable character it was purchased by the district at a cost of $410,000. This purchase was made on the 1st day of July, 1890. Since that time the board of directors have diligently prosecuted the work of completing the distributing branches, and as a result almost all of the land in the district is within easy access of the water for irrigation. The work of distribution is not entirely completed but is mainly done and is practically at an end. There is no reason why every farmer may not have all the water he may need for irrigation at the coming season. The pay roll of the district during this constructive period has been very large and expenses correspondingly heavy. But the work which has been done will never have to be repeated, and if every acre in the district were actually irrigated the cost would be but a trifle more than the expense which had to be met during the last season. The engineer most familiar with the situation estimates that a further expenditure of $65,000 will complete the system. The interest on this last-named amount at 6 per cent per annum would be $3,900, and this represents the additional amount which would have to be raised on interest account above what was raised for last year. The expense of officering the district would not be materially more if every acre in it were actually irrigated. If the system is completed and every one may have water by applying for it, the cost of supply should be determined in dividing the total acreage by the total expense, and that will give the average cost per acre. The levy for 1891 (covering interest fund and general expense fund) will raise something over $55,000, and this sum, divided by the total acreage, 130,000 acres, gives an average cost of something over 40 cents per acre. Before the district

was organized the corporation which owned the canal furnished water on the following terms: $10 per acre for a water right and a further charge of $1 per annum per acre for supplying the water. Counting interest at the rate of 10 per cent per annum (a rate which would have to be paid for small loans in the part of the State where this district is situated), the annual cost of irrigating each acre before the district was organized was $2. You can easily arrive at a fair estimate of the cost of this district irrigation with these figures before you. They have expended $410,000 for the main canal and the estimate of finishing the system is $65,000 more. This limit will enable the board of directors to cancel $200,000 of the bonds voted by the people for the perfection of a system. That is not very disappointing to the people I would say. By consulting the law one will be able to arrive at an approximately correct estimate of the current expense of running the district. The board of directors are required to meet at least once a month. When the system is completed they would not meet oftener. For one meeting each director would get $4 and mileage to the place of meeting from his residence. The other officers get such compensation as the board may fix, provided that the people of the district can vote a salary schedule at any regular election.

Mr. Wright states of other district matters in the valley of the San Joaquin that the Sunset district, as it is termed, to the west of Fresno, and comprising a very large portion of the comparatively low tableland region which make up the eastern slope of the Coast Range, is now engaged in making the permanent surveys necessary for the competitive plans they will need in order to carry on their system. The usual preliminary court proceedings necessary to establish the legitimacy and legal character of their organization have been successfully carried through the courts. The establishment of this district, if successful, will open up a great range of fertile country now entirely given over to very sparsely occupied sheep and cattle ranches.

A section profile of the San Joaquin Valley, passing through Fresno City as a central point and following the mountains to their summits on either side of the valley, will reach the summit of the Sierra Nevada at or near Mount Whitney on the east. On the west it will pass just north of San Carlos on the famous Panoche Grande grant. On the extreme eastern point the elevation will be over 14,000 feet, on the extreme western end it will be about 6,000 feet. In the center, a few miles west of Fresno City, the valley will be at or near sea level. On the eastern range the precipitation at the highest point will be not less than 75 or 80 inches per annum. On the western it will be from 28 to 35. At the lowest point in the valley it will not exceed 7 inches. Nearly all of the streams from which an irrigation supply is derived for the San Joaquin Valley, head in the Sierra Nevada Range, finding their sources at the base or on the sides of Mount Whitney. The streams of the Coast Range run toward the Pacific. As a result of these topographical conditions, the western side of the lower San Joaquin Valley has been deemed too arid to be utilized for irrigation purposes. The plan of the Sunset district managers involves the carrying of a water supply from the east side by means of a costly flume across the lowest portion of the great valley. It is this situation that gives such importance to their enterprise. The development of a water supply upon the Coast Range is too hazardous a plan to be undertaken at present, and so it becomes more practicable to furnish the same from the surplus of the eastern streams. Great prizes, commercially speaking, are presented to the minds of men of organizing and speculative character in that region by the possibility still before them of obtaining a profitable control of the surplus and storm waters of streams like the King River. Doubtless this possibility adds a great deal to the tenacity with which the district system has been fought. The recent decision of the Supreme Court as to the legality of the Madera district, also a part of this great valley, is one of magnitude in its possible effect upon the system of large landowning and of water monopoly. The Madera district has an area of 330,000 acres, and under present circumstances more than one-third of the land is under the control of six owners; while the entire acreage irrigated as to water is tributary to two or three companies.

The great canal and other works in the Modesto and Turlock districts are reported by Mr. Wright to be proceeding with considerable rapidity. He says:

> The great dam above La Grange will probably be completed within six months or less time (November, 1891). They have got high enough now to be independent of the rises of the winter and the work will go on without interruption until completed. The entire cost of construction in Modesto district will fall $200,000 below the amount provided for in the bond issue, while in Turlock district it will exceed the estimate by about the same figure. We expect that both of these districts will be supplied with water in time for the spring of 1893, or about one year from this date. This means that more than one-quarter million acres will be redeemed in these two districts alone.

The valley of the Upper Sacramento is one of the great wheat-growing regions of the State of California. In the valley the farms assume the character of large plantations. The smallest seldom ranges below 500 and then run up all the way to 40,000 acres. During the summer work of the special agent he drove over a portion of Colusa County for the purpose of examining the extensive works of the central irrigation district. The wheat harvest was in progress of reaping and gathering, as was the case also in Stanislaus County. It was a remarkable sight to see the great double-header machines drawn by from 24 to 36 mules and attended by from 5 to 10 men, making swaths often a mile in length, reaping, thrashing, and sacking the grain while in progress. The enormous areas of golden grain, ripening in the unblinking sunlight beneath the cloudless skies of central California, almost unvocal of human voices, with scarcely a dwelling in sight, and nothing to be seen but the monstrous machinery, and the enormous area of unfenced grain, was indeed a striking spectacle. One could but sympathize with the bitter remark of a prominent public man with whom the journey in Stanislaus County was made, as we looked upon the huge machine in operation: "I want men, not things, to inhabit this country. That is why I am for irrigation." In Colusa County, the center of the Sacremento Valley during the last decade, according to the United States census, the average size of the holding of land to each individual owner has increased considerably. The farm inhabitants have lessened in numbers.

The foothill sections on either side of this valley are held in farms of moderate size, though much larger than the average fruit-holdings in Southern California. The farmers have been working down from the foothills into the valley and find themselves almost inevitably arrayed against the greater land-owning interest. The orchard is a profitable feature of the foothills region and the commercial value of California fruit is stimulating great horticultural activity. This again creates a demand for the advantages embodied in the irrigation district system. As a consequence of the feeling on that subject three districts have been formed in Colusa County. The majority of votes cast in favor of this action by no means represents the majority of acres embraced. That fact probably accounts for the assertive vigor of the anti-district irrigation feeling. It is asserted that the cost of the great works now being constructed in the Central district will be so much larger than the official estimate as to result in the practical bankruptcy of the people interested. Mr. Wright, the attorney for the district, states that—

> The people first voted, I believe, $750,000 in bonds. If $200,000 more are required it will still leave the cost at less than $6 per acre. This cost per acre would be just what the people of Alta district paid for three years' water before the district was formed.

C. E. Grunsky, the civil engineer in charge of the works, says, under date of December 1, 1891:

> The cost of our work as compared with the original estimates, which were of a general nature and made before the plans of work were fully matured, is clearly and correctly set forth in W. H. Hall's report on the district. It is a fact that right of way has in some instances cost an excessive amount, but in submitting my original report I stated to the board of directors that I had not included right of way in my estimate because I was not then sufficiently familiar with public sentiment in the district to know at what value to figure the lands and privileges to be condemned. Excessive cost of right of way can therefore only be compared with an indefinite general estimate of its value as originally fixed by the board.
>
> It is clearly shown that a further issue of bonds will be necessary to complete the district works. No new contracts have been awarded since Mr. Hall's report was written and work for this season has been suspended.

Mr. William Ham. Hall, C. E., in a report on the district under consideration, states:

> At this day over 140,000 of its 156,540 acres are in tillage for cereals. Fruits and vines are in a small way and locally grown, and alfalfa in especially favored localities, where water can be cheaply pumped. There are probably not over a couple of thousand acres in the district which have not been in tillage for a number of years.

Wheat-growing is not profitable for small landowners. In the Central district of Colusa, according to Mr. Hall, there are 40 owners of over 1,000 acres each, with an aggregate among them of 89,000 acres or more than half the area of the district. The whole district contains but 180 owners of farming land. On these lands and outside two small towns there are but 260 voters—that is, 1.06 voters to the square mile. Ordinarily this would make five persons on that area, but as a considerable number are laborers and unmarried, the permanent population is very small indeed. A very large proportion of the landowners are not residents of the districts, and some of them not even of the State or nation. The upper Sacramento Valley has not until recently been discussed for irrigation purposes, but the former State engineer declares that the area is admirably adapted for farming by irrigation and small holdings. He gives the following succinct account of the system:

> As planned by the district chief engineer (Mr. Grunsky) the Central district irrigation works will consist of (1) a main canal, 61.35 miles in length, having in successive divisions 60, 55, 50, and so on down to 25 feet of bottom width, with side slopes of 1 in 1½, and to carry 6 feet depth of water throughout on a uniform gradient of 1 in 1,000; and (2) 199 miles of distributary canals and ditches, varying in width from 8 to 20 feet on the bottom, and to carry water from 2 to 4 feet in depth on the slopes of the country generally across the district, as modified by occasional check weirs and drops to be built in these water ways. These canals and ditches are expected to distribute water to the highest point of each section (640 acres) of land.

The charge has been made by the opposition to the district that the total cost will not be less than $2,000,000; the estimated cost is $940,354. There remains of this sum to be contracted for, $304,602. Engineer Hall's statement—and from his position as the engineer adviser of bankers engaged in disposing of irrigation bonds, it must be deemed very conservative—is that the work can be put in good running order, and the 10 per cent discount on the sale of bonds be allowed on a total issue in bonds of $1,000,000, or a field and construction cost of $945,000. As the original amount of bond issue was $750,000, this leaves $250,000 to be raised for completing the works. The assessed value of farming lands in the central district for the year 1890–'91 was $2,188,278, making a mean valuation per acre of $13.97. The best farming lands in that district will sell for an average of about $55 per acre. It is the opinion of Mr. Hall that the completion and operation of the canal system in the central district of Colusa will, within five years thereafter, double the value of every acre of land. He estimates the present market or mortgage value of the whole acreage at $4,500,000. As a business operation the bonded indebtedness to complete this irrigation system when charged entirely against the farming lands will make a debt rating at $\$6.42\frac{6}{10}$ per acre. The valuation under the tax levy is now $13.97. For mortgage purposes the average value of the acre would be $30. Doubling that figure and taking five years for the period of increase the rate will be 20 per cent per annum or dollar for dollar at the end of that time.

These instances have been referred to, first, because of the controversy in the California press, and second, because of the light they shed on the questions involved pro and con in connection with the organization of municipal districts for the purpose of constructing works and administering a water supply to be used in the cultivation of land by irrigation. Many grave matters are embraced within such a discussion.

FRUIT CULTURE BY IRRIGATION.

The California State Board of Trade, on September 8, 1891, authorized the statement that 2,075 carloads of fruit had been shipped East as against 1,750 carloads for the same date last year. It is interesting to note that the shipments of vegetables for last year according to the same authority was 2,492 carloads of 10 tons each. This product, which includes potatoes and beans, is of more money value to the State than the entire citrus growth, a fact not very generally known. The maturing of these vegetable products is as a rule at that period of the year when elsewhere, except in Southern seaboard and Gulf States, such production remains a climatic impossibility. The chief shipments of such winter-grown vegetables are from sections of Los Angeles, Orange, and San Bernardino counties favorably affected by natural sub-irrigation. There are considerable areas, especially in Los Angeles County, where the drainage of higher sections, as well also as the irrigation seepage affect the moisture of land lying nearer the coast and at a lower altitude than the more inland section. As a consequence, much of this area has not been placed "under ditch." It produces vigorously, and being almost semi-tropical in climatic conditions, with the favorable facts of winter rains and sub or phreatic moisture, it has developed rapidly as a producer of early vegetables. The returns of the State Board of Trade are in proof. In the course of his inquiry in the several States of the arid region, the special agent found a considerable demand for statistics of horticultural and vegetable products. At present California is at the front, but the rapid growth of fruit culture as stimulated by irrigation, and active profits, is causing the rapid planting of large orchard areas in Colorado, New Mexico, northwest Montana, eastern Washington, and southwestern Idaho. Utah is also a good horticultural field, and western Colorado is rapidly taking a large place. Mr. L. C. McAfee, identified with the enterprises of Haggin & Tevis, in Kern County, Cal., expressed a general desire in the following suggestion made to the special agent. After remarking that he had written the Department on the subject, Mr. McAfee said:

> There is great difficulty in obtaining accurate statistics of fruit and vegetables. The way it presents itself to me is from a commercial standpoint. California is capable of producing fruits and vegetables of almost every kind, and the facilities of

transportation have so increased that the world is our market; therefore we desire to find out what the world is producing and what the world demands. What is most in demand is what we would first desire to raise, and in order to accomplish that object we ought to have accurate statistics of production. For example, a compilation that would show the whole fruit production and consumption of the world, by counties, would cover this desire. There is another thing which such a statistical report would show, and that is, the horticultaral importance and agricultural value of the arid region. If only one acre in four could be reclaimed it would still bring the product of the arid region up to the product of the balance of the country. I think this simple statement is sufficient of itself to show the absolute necessity and superabounding importance that it holds. This land can only be associated with the valley of the Nile, which is the ideal of agricultural production.

The matter of just legislation on the subject of reclamation of arid lands by irrigation is of the gravest importance, and the Agricultural Department ought to be sustained with great liberality, because it is undertaking to advance knowledge on a new and important enterprise, which needs guidance and direction. The irrigator requires consideration even more than the farmers in the humid States, because irrigation requires more intelligence and arrangement. They can not work singly at all; it requires associated effort to do it properly. Irrigation, more than any other branch of our economic life, demands inquiry and experimentation. I am very emphatic on that. I do not say that we want it, but I say that our people as an integral part of the Government demand it. The importance of the enlargement of the powers of the Agricultural Department can be easily understood, because here are 1,000,000,000 acres of land that are practically worthless without irrigation. With it they not merely take stand with other agricultural lands, but far surpass them in their intrinsic value, and it can be put down as an assured fact that these lands will produce grass crops alone of from $100 to $150 per acre, and represent a minimum production of $50,000,000,000 per year.

No better object lesson of the growth of irrigation in California is to be presented than by a glance at the development of the citrus industries. These fruits are now raised for the purpose of commerce from the Southern border of San Diego line to Red Bluff, in Tehama County. Oranges have been raised much farther north, but only as experiments or for ornament in gardens. The six most southerly counties raise the greater part of the product, and so industriously has their staple been advertised that Eastern readers hardly think of southern California in any other light than as a citrus-growing region. In 1870 there were 7,086 lemon trees and 38,991 orange trees in the State of California. The following table from the report of Mr. B. M. Le Long, secretary of the State Board of Horticulture, will show the amount of increase since the general adoption of irrigation:

Counties.	Orange trees.		Lemon trees.	
	Bearing.	Not bearing.	Bearing.	Not bearing.
SOUTHERN.				
Los Angeles	475, 726	511, 376	47, 403	29, 524
Orange (estimated)	89, 260	51, 769	5, 097	19, 969
San Bernardino	391, 656	1, 895, 544	24, 066	155, 934
San Diego	26, 715	177, 311	7, 006	58, 916
	983, 357	2, 636, 000	83, 572	264, 343
SOUTHERN COAST AND RANGE.				
Santa Barbara	6, 700	37, 500	3, 750	9, 400
San Luis Obispo	1, 200	4, 600	600	1, 950
Ventura	8, 614	55, 056	4, 215	32, 512
	16, 514	97, 156	8, 565	43, 862
COAST.				
Monterey	75	146	14	....
Santa Clara	920	415	156	175
Santa Cruz	120	96	44	80
San Meteo	126	244	50	....
	1, 241	901	264	255

Counties.	Orange trees.		Lemon trees.	
	Bearing.	Not bearing.	Bearing.	Not bearing.
SAN JOAQUIN VALLEY.				
Fresno	1, 113	4, 828	400	980
Kern	425	852	275	365
Merced	325	625	215	420
Tulare	1, 580	1, 750	455	1, 430
San Joaquin	112	2, 640	22	65
	3, 555	10, 695	1, 367	3, 260
THE BAY COUNTIES.				
Alameda	722	1, 874	525	622
Contra Costa	155	243	118	140
Marin	225	23	16	....
Napa	455	920	378	254
Solano	1, 303	2, 114	189	215
Sonoma	1, 619	1, 466	255	840
	4, 479	6, 530	1, 481	2, 091
SACRAMENTO VALLEY.				
Colusa	195	6, 728	44	54
Lake	125	236	....	....
Sacramento	1, 310	12, 300	166	976
Sutter	353	3, 144	27	125
Yolo	485	856	214	309
Yuba	3, 132	18, 027	321	....
	5, 600	41, 291	778	1, 464
FOOTHILLS.				
Amador	72	44	34	18
Butte	3, 007	116, 005	362	1, 400
Calaveras	145	85	18	200
El Dorado	108	176	30	265
Mariposa	28	145	18	115
Nevada	100	200	....	....
Placer	6, 055	5, 480	595	1, 300
Stanislaus	1, 154	16, 642	254	314
Tehama	380	866	104	114
	11, 049	139, 643	1, 459	3, 726
NORTHERN.				
Shasta	74	125	44	....

RECAPITULATION.

Southern	983, 357	2, 636, 000	83, 572	264, 343
Southern coast and range	16, 514	97, 156	8, 565	43, 862
Coast range	1, 241	901	264	255
San Joaquin Valley	3, 555	10, 695	1, 367	3, 260
The bay counties	4, 479	6, 530	1, 481	2, 071
Sacramento	5, 600	141, 291	1, 778	1, 464
Foothills	11, 049	139, 643	1, 459	3, 726
Northern	74	125	44	....
	1, 025, 869	2, 932, 341	97, 530	318, 981

Total number of orange and lemon trees in the State of California, 4,374,721.

It will be observed that the citrus cultivation is largely on the increase, taking previous planting as a basis of calculation, in the southern, coast, and coast-range counties. This is especially so in the foothills counties. A portion of this sub-classification may be disputed, as in the case of Stanislaus County, but for this purpose it is in the main quite accurate enough. The figures and others that might be given offer a warrant for Mr. McAffee's suggestion as to a report on horticulture.

ARID CLIMATOLOGY.

This report gathers considerable utility from the use made in the review of several of the States and Territories, so far as climatology is concerned, of the admirable report "Irrigation and water storage in the arid region" (Fifty-first Congress, second session, Ex. Doc. No. 287). The Chief Signal Officer and former chief of the Weather Service tersely review the meteorological conditions of the arid region and present careful tables of precipitation, etc. His contention is one that appeals to practical common-sense observation and judgment.

"Identical rainfalls do not suggest," he says, "that any industry or pursuit in which rain is an important element would succeed as far as water is concerned equally at either place." This reference is made on the rainfall figures at Pittsburg, Pa., and Julian, San Diego, Cal., at which places the precipitation is, respectively, over 36 and 37 inches per annum. The difference in effects lies in the difference in distribution by precipitation. At Pittsburg the rainfall is fairly felt throughout the year. At Julian for six months the fall ranges from "no trace" to "fifty-five hundredths of an inch." The rainy season at Julian begins in November and ends in April. For irrigation, whether in the Pacific slope or in the Great Plains, or in the intra-mountain basins between the Rockies and the Sierra Nevada, the vital necessity lies in the distribution more than in the quantity of precipitation. In this relation, then, it is well to emphasize by reproduction the facts involved in the following brief tables of precipitation and temperature presented in the "Progress report," 1890, on "Irrigation in the United States" (pp. 128, 129, 130), published for the office of Irrigation Inquiry by the Fifty-first Congress and the Department of Agriculture. The significance of these summary tabulations consists in the evidence they offer of the seasonal distribution of the rain. If a map of the arid region be taken and the stations given be traced thereon by lines of given longitude, it will be seen that the difference between winter and summer rainfalls rise and fall from a line near to or running on the one hundred and seventh meridian of west longitude like regular steps. East of the line given the summer precipitation ranges it will be seen 7.45 inches at Fort Carter, Mont., to 15.88 inches at Fort Sill, Ind. T., on or near the ninety-seventh meridian, while westward from the line of one hundred and seventh longitude it falls 6.64 inches at Prescott, Ariz., to forty hundredths at Fresno, Cal. These deductions are emphasized by the following summarized tables:

	West longitude.	Average annual mean north to south.
East of 107°:	*Degrees.*	*Inches.*
One	97	26.67
Two	102	19.12
Three	105	13.83
Four	107	12.83
West of 107°:		
Five	1,120	12.22
Six	1,170	14.00
Seven	121 to 125	18.00

In the progress report the special agent in charge suggested that in such seasonal divergencies may be found the key to some of the weightier problems presented to the irrigator. The tables of stations, etc., are given as follows:

Mean seasonal rainfall, mean normal (seasonal) temperature, and elevations of stations named, lying within the semiarid and arid region, west of the ninety-seventh meridian of longitude west of Greenwich and east of the Cascade and Coast Ranges, on the Pacific coast.

I.—ON OR NEAR THE NINETY-SEVENTH MERIDIAN.

State.	Station.	Mean rainfall.			Annual average rainfall.	Mean normal temperature.		Elevation above sea level.
		Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.		Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*
North Dakota	Pembina	2.88	13.92	4.40	21.06	....	....	791
Do	Morehead	4.72	14.24	6.28	25.61	....	....	903
South Dakota	Yankton	5.76	15.80	5.80	27.84	23.3	62.4	1,234
Kansas	Concordia	5.32	13.60	5.88	25.58	....	....	1,384
Indian Territory	Fort Sill	6.20	15.88	9.44	32.28	43.3	72.6	1,200
Texas	San Antonio	8.56	12.80	9.92	31.63	55.9	77.2	781

II.—ON OR NEAR THE ONE HUNDRED AND SECOND MERIDIAN.

North Dakota	Bismarck	4.80	11.12	3.76	19.57	14.6	57.1	1,681
South Dakota	Fort Sully	3.20	10.04	2.14	15.81	....	....	1,600
Nebraska	North Platte	3.44	11.84	3.80	19.11	30.7	62.6	2,841
Colorado	Las Animas	2.56	8.48	2.24	13.46	....	....	3,899
Texas	Abilene	6.00	9.72	8.24	24.78	....	....	1,748
Do	Fort Stockton	2.76	7.96	8.20	20.09	....	....	3,010

III.—ON OR NEAR THE ONE HUNDRED AND FIFTH MERIDIAN.

Montana	Poplar River	2.08	7.76	2.24	10.79	....	....	2,002
Wyoming	Cheyenne	6.32	6.56	7.84	9.96	29.4	56.0	6,105
Colorado	Denver	4.27	7.04	3.15	14.58	34.2	61.0	5,281
Texas	Fort Davis	1.95	10.45	6.87	17.71	48.2	69.3	4,928

IV.—ON OR NEAR THE ONE HUNDRED AND SEVENTH MERIDIAN.

Montana	Fort Assinniboine	3.41	9.02	3.12	16.38	19.8	55.9	2,690
Do	Fort Custer	3.24	7.54	2.95	13.64	28.7	59.1	3,040
Colorado	Montrose	2.88	3.48	3.32	9.34	....	....	5,780
New Mexico	Santa Fé	2.49	7.70	4.24	13.94	33.6	59.2	7,026
Texas	El Paso	1.77	5.49	3.61	11.08	49.3	74.4	3.796

V.—ON OR NEAR THE ONE HUNDRED AND TWELFTH MERIDIAN.

Montana	Helena	.52	5.68	3.92	13.89	25.1	55.3	4,069
Utah	Salt Lake	7.24	3.00	5.48	16.68	34.6	63.6	4,348
Arizona	Prescott	5.88	6.64	4.48	17.06	....	....	5,389
Do	Phœnix	2.40	1.44	3.00	7.38	55.9	78.0	1,120

VI.—ON OR NEAR THE ONE HUNDRED AND SEVENTEENTH MERIDIAN.

Washington	Spokane Falls	7.52	4.44	7.56	19.08	32.1	58.5	1,909
Idaho	Boisé City	6.24	2.56	4.60	13.47	35.5	61.5	2,750
Nevada	Winnemucca	3.80	1.76	2.92	8.92	....	....	4,340
California	Tehachapi	7.64	.64	2.72	11.04	....	....	3,964

Mean seasonal rainfall, mean normal (seasonal) temperature, etc.—Continued.

VII.—STATIONS NEAR THE ONE HUNDRED AND TWENTY-FIRST TO THE ONE HUNDRED AND TWENTY-FIFTH MERIDIANS.

State.	Station.	Mean rainfall.			Annual average rainfall.	Mean normal temperature.		Elevation above sea level.
		Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.		Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*
Washington	Fort Simcoe	6.72	1.12	2.72	10.61	....	....	....
Do	Ellensburg	3.72	1.76	3.44	8.97	....	....	....
Oregon	Fort Dallas	9.72	2.08	10.12	21.96	....	....	350
Do	Linkville	8.56	3.48	4.92	14.41	36.0	55.2	....
California	Berryvale	5.48	1.20	13.00	28.84	....	....	....
Do	Red Bluff	17.92	1.60	10.04	25.99	49.9	71.2	342
Do	Sacramento	8.44	1.56	5.80	19.69	50.1	67.4	65
Do	Stockton	8.92	.68	4.28	13.91	....	....	....
Do	Merced	7.28	.72	3.72	11.75	....	....	17
Do	Fresno	5.36	.40	3.00	8.79	....	....	295
Do	Visalia	6.72	.60	4.00	9.25	....	....	348
Do	Los Angeles	10.92	.68	4.56	16.3	55.7	67.0	371
Do	San Diego	6.68	.64	3.36	10.26	55.5	64.7	66

While with Lieut. Glassford and other experts, agreement is had on the general proposition that 20 inches are necessary for industrial use there is evidence to show that as low as 15 inches will serve under proper conditions of soil, etc., if the same can be secured when needed. This conclusion will be found sustained as Gen. Greeley states:

> The latest rainfall maps of the United States compiled at the office of the Chief Signal Officer (March) show that there are enormous areas of country in the so-called arid regions where the rainfall exceeds 15 inches (by which isohyetal, or line of equal rainfall, the arid region is, by some, limited), and even very large areas over which the annual precipitation exceeds 20 inches, and in lesser areas 25 inches.

The discussion of evaporation in Gen. Greeley's paper is very interesting as well as of value. A summary of some of the data is given in the annexed table, prepared from the Weather Service monograph (p. 10, 11, 12).

States and localities.	Total amount (cubic measure).	Average depth of possible evaporation.
		Inches.
Arizona	145.9	80
California	170.9	87
Colorado	108.6	69
Nevada	145.8	90
New Mexico	146.2	78
Utah	90.9	68
Sweetwater, Cal	....	*29.88
Salt Lake †	....	74.04
Albuquerque	....	80
Lake George, New South Wales †	....	46
Caspian Sea †	....	43

* These figures are for seven months only.

† Salt Lake has a surface of 4,700, Lake George one of 80, and the Caspian Sea a surface area of 80,000 square miles.

The conclusion in part arrived at by Gen. Greeley as to the practicability of storage will bear quoting. He says:

> What has already been said shows, however, that over very extensive sections of the arid regions the heavy rains from which must be derived waste-water for irrigat-

ing purposes come at such a period of the year as to render it necessary to keep the water stored for a long time before it can be generally used for irrigating purposes; that such storage occurs in countries and under conditions where evaporation proceeds rapidly and to a degree almost unequaled in any other part of the world; and also, that the violent rainfalls are in such quantities and cover such an area of country that the whole of these waters can not be store ; and that where storage facilities are provided they must be of most durable and solid construction, with such facilities for carrying off waste water as will render the recurrence of calamities similar to the great disaster on the Hassayampa River in Arizona practically impossible.

The ocean "passage winds" are important to our western irrigation crops, but their humid effects are most strongly felt upon the northwest portion of the Pacific coast. The movement across the ocean plane of these winds tends steadily to west by north. As a result of this, the largest share of the aqueous contents of such winds is precipitated upon the comparatively narrow shore plane of Oregon and Washington, giving thereon the greatest recorded rainfall within the United States. The coast line break at Puget Sound acts as a funnel to draw inward a marked share of this oceanic precipitation, and as the continental topography at this point is considerably less in altitude than further south, we see a marked increase of humidity along the western slopes of the northwest Rockies in Washington and Montana. There is also a considerable influence exercised by what are locally termed the "Chinook" winds that, laden with moisture from the sea, are enabled to pass over low portions of the range and modify the winter climate of such intra-mountain settlements as Helena, Mont., and Boisé City, Idaho, as well as by their deposition of moisture to make Idaho's panhandle section and the eastern foothills region of Washington a subhumid area, fertile to a degree, and largely capable of sustaining cultivation without irrigation, though like the largest portion of the Great Plains the artificial use of water in the ripening months will surely increase security and thereby add greatly to the value of industrial life.

The excess of precipitation along the northwest coast is so marked and peculiar as to warrant a brief reference. Take, for illustration, the record of annual precipitation at San Francisco, Cal., and Tatoosh, Wash., at the entrance of Puget Sound; San Francisco, reports 23.80 inches of rainfall; Tatoosh, one of 94.42, a difference of 70.62 inches. The theoretical difference, as figured by the meteorologist's rule, of a certain per cent of moisture absorbed by the passage winds for each mile of ocean surface they traverse, is much less. Tatoosh is set down under the rule given as entitled to 61.97, a difference of 32.45 inches less than the actual rainfall. The theoretical difference between San Francisco and Tatoosh is as 27.29 to 61.97, or 34.68 inches. These figures strongly illustrate the remarkable northwest tendency of the actual rainfall. Doubtless it will aid greatly in explaining glacier action in Alaska by the evidence given of a high precipitation in a region of very low temperature. The "humid constitution" of the southwest passage wind accounts normally for a considerable portion of the peculiar deposition of the ocean moisture; yet the fact that the increase is in proportion to the northern in latitude points to other causes than the one first named. The materials for explanation are scanty, and the meteorologist does not, as yet, offer any. I venture to suggest that the polar influences may possibly have something to do with the cosmic movement of winds which bear moisture to our Pacific coast, and that the aqueous current thus drawn northeastward may hereafter appear as part of the Atlantic humidity to the south and east.

The analytical summary hereafter given of climatic factors within our Cordilleran region shows how the four barometrical "constants" of two "highs" and two "lows" relate themselves, in general terms, to the northwest. When the area of high barometer, which is a "constant" factor in Oregon and Washington weather, overlies that region the center is probably far to seaward, subject to violent perturbation, and produces storms of the cyclonic type. The eastward movement is checked by the Cascade Range and the Rockies, and the result is heavy precipitation, especially in Washington. The eastward "low" beats against the mountain barriers, and the "high," as it rises and crosses them, remains steadfast, though very much desiccated, over the northern plateau and adjacent parts of the Great Basin. The "low" barometrical area generally has its center near the coast, and its influence as to rain is usually spent upon the shore plane southward to San Francisco, very rarely passing beyond that point. It will be observed by this brief outline how favorable all the conditions are for the extreme northwest section, alike for present irrigation and future water storage.

The following condensed table of rainfall is one of the most useful presented by the Weather Service (p. 19), report on Arid Climatology:

Annual rainfall in sections named.

State.	Elevation.	Area in square miles.	Cubic miles of rainfall.	Average depth of rainfall in inches.
Arizona	Sea level to 3,000 feet	38, 670	5. 3	8. 63
	3,000 to 5,000 feet	27, 230	6. 3	14. 56
	5,000 feet and over	47, 120	10. 7	14. 30
	Whole State	113, 020	22. 3	12. 42
California	Sea level to 2,000 feet	82, 290	27. 9	21. 64
	2,000 to 5,000 feet	53, 530	18. 2	21. 66
	5,000 to 7,000 feet	17, 334	7. 5	27. 56
	7,000 feet and over	6, 246	2. 7	27. 75
	Whole State	159, 400	56. 3	22. 56
Colorado	4,000 feet and less	8, 773	1. 5	11. 15
	4,000 to 5,000 feet	18, 031	3. 2	11. 78
	5,000 to 7,000 feet	31, 314	6. 1	12. 74
	7,000 feet and over	45, 885	9. 2	13. 12
	Whole State	104, 500	20. 0	12. 61
Nevada	Less than 5,000 feet	39, 759	5. 0	7. 98
	5,000 to 7,000 feet	57, 654	10. 7	11. 85
	7,000 feet and over	14, 590	2. 9	12. 92
	Whole State	112, 000	18. 6	10. 64
New Mexico	4,000 feet and less	6, 996	1. 1	10. 14
	4,000 to 5,000 feet	34, 407	6. 1	11. 59
	5,000 to 7,000 feet	57, 503	12. 4	14. 13
	7,000 feet and over	22, 300	5. 6	16. 34
	Whole State	121, 200	25. 2	13. 62
Utah	5,000 feet and less	28, 615	4. 0	9. 00
	5,000 to 7,000 feet	35, 444	6. 5	11. 59
	7,000 feet and over	20, 441	3. 2	6. 97
	Whole State	84, 500	13. 7	10. 32

THE AËRATION OF WATER AND IRRIGATION.

With the application of water properly aërated and the opening of the earth by intensive cultivation to the same atmospheric forces, the irrigation farmer must naturally study the crops best adapted to his conditions. Horticulture is a special culture, requiring careful conditions of place, soil, and climate. The general farmer will necessarily take a wide range. The capacity of plants to penetrate the soil deeply, to draw water supplies by capillary attraction, as well as their differing demands for plant food, are all to be considered. The relations of plants also to alkali soils are of very considerable importance. The most valuable crops yet grown in the arid section are the alfalfa, clover, and other leguminous plants; also the sugar and common beets, with other root and tuber varieties. All cereals and small grains generally derive their nourishment from the first 5 or 6 inches of top soil. Hence the rapid growth that is often seen under irrigation, clear skies, and warm weather. It is a matter of constant remark after planting clover or alfalfa, the latter especially, that the land produces finer crops of wheat, oats, or other of the small grains. The secret of this for irrigators is, that leguminous plants require and contain to an appreciable degree less water, while their roots go deeper down in seeking nutriment.

The aëration of water is an almost indispensable condition of successful cultivation by means of irrigation. Atmospheric gases are always present in the soil. Combined with water, they are essential to the processes by which the mineral constituents are dissolved and their useful portions conveyed to the plant roots for sustenance and growth. The importance of atmospheric impregnation can be forcibly realized by recalling the fact that nitrogenous food is essential to plant life; that pure nitrogen, or azote, from which alone by combinations can such food be produced, comprises four-fifths of our atmosphere. All water absorbs air. The more it does so the better it becomes for use in irrigation. Its fertilizing powers increase rapidly by accelerating the direct and indirect absorption of nitrogen and of its various combinations, such as ammonia, phosphoric acid, potash, etc. Water itself is composed of oxygen and hydrogen in the ratio of 100 to 12½ by weight. Common air, according to Silliman, is composed of oxygen and nitrogen in the proportion by weight of 23 of the former and 77 of the latter. At the ordinary temperature water absorbs of air forty-six one-hundredths of its own volume. The rate will be in a liter* of water: Nitrogen, 65.1; oxygen, 34.9.

The enormous value of nitrogenous material has been forcibly illustrated by Dr. Wiley, department chemist, who has said that 80,000,000,000 pounds enter into the creation of one harvest in the United States,† the value of which is not less than $5,000,000,000.

This enormous mass of plant food is chiefly found as nitrates or albuminoids. All nitrogenous food material is converted before assimilation into nitrate acids or nitrates. Such combinations are soluble in water. The waste of such materials is as enormous and significant as the sum of its utility. Dr. Wiley declares that in the production of the cereals the annual total of phosphoric acid taken from the earth is nearly 3,000,000,000 pounds, while the loss of potash is not less than 4,000,000,000 pounds. Vast stores of such material are carried away by stream or river, and washed from the earth by floods. The enormous masses of silt borne by the streams to the ocean are loaded with nitrogen. This waste is almost ceaseless; nature's destructive or remolding forces are constant. They are not hindered, except by the skill, knowledge, and art of man. The essential food of plant life is thus continually diminishing, and without the artificial aids which knowledge alone points out, there is perpetual tendency to waste, disintegration, barrenness, and aridity. Hence it is that whatsoever tends to the preservation of all such materials belongs to the domain of economic conservation. The care and skill which cultivation under irrigation must create and bring into practical operation is a force the importance of which is hardly demonstrable by any known expressions of value at command.

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*1.0567 quarts, United States measure.

†Address before the New Jersey State Board of Agriculture, 1889.

To let the air into the water for irrigation is equally as important as to admit the air into the soil by efficient and intensive cultivation. Agricultural chemists are divided on the question of direct assimilation of nitrogen by water, either as rainfall or exposed phreatic supplies and bodies. Large quantities of ammonia and nitric acid are always found in rain water.

From a tabulation of the "Average composition of American feeding stuffs," computed and calculated by E. H. Jenkins and A. L. Winton, jr., and published in Experiment Station Record, July, 1891, Vol. 2, No. 12, United States Department of Agriculture, the following average results are obtained as to the average amount of water chemically found in certain food-plant groups:

	Average.	Remarks.
	Per cent.	
Cereal grasses	47.7	Four varieties and 63 analyses.
Other grasses	67.4	Six varieties and 90 analyses.
Legumes, grasses	75.1	Five varieties and 86 analyses.
Tubes, roots, bulbs, and other vegetables	93.7	Fourteen varieties and 104 analyses.

In Johnson's "How Crops Grow" (p. 39, ed. 1890) the following averages are given: Meadow grass, 71; red clover, 80; corn, 82; cabbage, 85; potato tubers, 75; sugar beets, 81; carrots, 86, and turnips 91 per cent.

The careful investigations constantly in progress at Rothamstead, England, shows that the yearly averages range from 54 to 135 per cent. In a gallon of water the ammonia ranged from 17 to 60 per cent, while of nitric acid the amount was 0.86. But these averages are not enough for the demands of agriculture, and land which is not supplied with the necessary quantity is soon exhausted. The nitrates are not only consumed by the plants, but as already shown, they are constantly being washed from the soil. A recent writer in the Noveau Revue discussing the productiveness of the earth declares it to be illimitable if a sufficient amount of nitrogenous material can be applied to the soil, and he further declares that this is entirely within the range of human skill and prevision. In this view then, the power of fixing as well as gathering nitrogen is of the utmost importance.

Professor Atwater, till recently director of Experimental Stations in the Department of Agriculture, in conjunction with such able chemists as Hellriegel, Muntz, Berteloc, and others, believes the weight of testimony supports his view—that nitrogen is absorbed or conveyed by water directly from the atmosphere. Other chemists hold to the view that only a portion of nitrogenous matter is furnished by rainfall, the balance and the more important part being obtained through the direct influence of plant growth itself. In either way, irrigationists can readily perceive the importance of fully aërating their supply of water before distributing the same to the land. It may be suggested that such insistence upon the value of aëration would necessarily affect the value of systems of conveyance of water by pipes or other underground conduits. This is not necessarily correct, as sufficient atmospheric exposure is usually obtained in streams, standing waters, and reservoirs, before conveyance for irrigation actually begins. But it is almost essential that direct underground supplies shall be exposed to the atmosphere before use. Certainly such aërated water will be more valuable for farm purposes. It is doubtless true that artesian and other phreatic waters contain a proportion of nitrogenous material, though potash does not often appear in the analysis, and of phosphoric acid there is no mention made.

The author of "Agricultural Hydraulics," M. J. Charpentier de Cossigny, gives the following interesting presentation of the manner in which "gas in solution in water" relates itself to plant life and the cultivation of the soil by means of irrigation:

> It must be observed that the oxygen and nitrogen not being in combination act separately, according to their affinity for the liquid, so that the water is always found to have absorbed, following the proportions of the atmosphere, more oxygen than nitrogen.
>
> We will investigate the rôle played by these gases introduced by irrigation waters into the cultivable soil. Oxygen is not so much a food for plants as it is one of the principal agents in the the complex phenomena by which the sap is prepared in the depths of the earth. It slowly burns away the organic matter of vegetable or even animal origin mixed with the soil; it transforms little by little the insoluble matter into a humus which is soluble, and which can be easily assimilated by plants. The oxygen, moreover, holds and returns to the soil at need the sulphur found there in the state of sulphates (inoffensive salts), to the exclusion of the sulphurets, especially the sulphuretted hydrogen, which last is frequently the product of putrid decompositions and which is poisonous to plant life. Finally, this same gas—a life-giving agent par excellence—in encountering calcareous or alkaline matter in the soil, causes the azote or nitrate mixed therein to pass into an azotic state. * * *
>
> As yet no experiment has been made determining the exact part played by the water in introducing azote into the soil, and we can only advance arguments in favor of our presumptions. Is this azote finally disengaged into the atmosphere? It would seem probable for that portion corresponding to the water, which is evaporated on the surface of the soil, under the combined action of the sun and winds. But this is only a small portion of the irrigation, for independently of the limited part which sometimes penetrates to great depths in the earth, there is still another important portion which, after having passed through the plant with the running sap, is returned by transpiration to the atmosphere. But vegetables do not exhale any nitrogen. There is reason to believe, then, that the azote found in solution in that portion of the water of which we are speaking must have become fixed there, either by the soil a little in advance of the penetration of the water into the plants through the roots or else by the plants themselves during the passage of the water through them. In the first case it would not have been impossible for a nitrification of the azote to have occurred, owing to the action of the oxygen and the alkaline substances contained in the water before its absorption by the plants. A gas dissolved in water is in a veritable state of liquefaction. and the molecules are infinitely more condensed than when they are in a gaseous state, which considerably augments the energy of the physical force. Who has not noticed, for instance, that the action of the air has no effect on iron nor on most other minerals when they are in a dry state, but that it oxidizes them as soon as water is introduced. Would it not also be possible for nitrogen—usually in an inert state—to become a more active principle when in solution?
>
> M. Hervé Mangon has experimented upon a prairie by irrigation through a whole season. At each irrigation he has measured the quantity of water appropriated and also the quantity which has afterwards escaped, not having been absorbed. He calculated the quantity of nitrogen furnished to the soil by known agents and the quantity found in the crop itself, and found the last quantity in excess of the first. Whence comes, then, this excess, except from the atmosphere, and through what channels, under what influences, and by what chemical aid does this substance penetrate into the earth? M. Georges has claimed that the azote (nitrogen) is directly absorbed by the leaves, but the truth of this hypothesis has not yet been demonstrated; and it is now generally believed that, through the intermediation of the soil and the roots, azotic matter passess into the organism of the plant.
>
> But water contains in solution not only oxygen and hydrogen, but carbonic acid also in various proportions. But the carbonic acid found in the water could not be accounted for by the quantity found in the atmosphere, without the intervention of other causes; one of these facts is that the water of the springs is more or less mixed with carbonic acid and their water is more or less mingled with that of the rivers themselves. On the other hand, Mangon found that irrigation water running along in narrow channels on the surface of the ground was found to

be much more highly charged with carbonic acid than before its passage over this prairie. Might it not be by means of a similar phenomena, that is produced during heavy rains on the surface of each field, that the waters of a river are much more highly charged with carbonic acid at the time of high water than at low water?

In any case this acid plays a very important rôle in vegetation. It is by means of it that water attacks solid rocks, sand, clay, etc., and extracts from these inert substances the fertilizing principles which are assimilated by the soil and which improve it. Water charged with carbonic acid carries with it, in penetrating the soil, the instrument whereby valuable substances are disengaged from it, such as potash and phosphoric acid, which would not otherwise be found either in the water itself or in the fertilizer applied.

* * * * * * *

We know, of course, that water is indispensable to culture and vegetation. The soil deprived of it entirely would either be reduced to a fine dust, incapable of giving that support to the roots of plants which they require, or would form so compact a mass as would be difficult to work with agricultural tools, and which would be almost impenetrable to the reaching out of fine threads of the roots. Water, moreover, seconded by the atmospheric gases with which the earth is usually impregnated, attacks the mineral constituents of the soil and by dissolving carries away from them the useful principles which are at once appropriated by the plants. Water also serves as a vehicle for the conveyance of all the active properties of the compost, and, in a word, water constitutes the principal part of the sap.

The sap absorbed by the spongioles or suckers of the hairy branches of the roots rises to the green parts of the plants and to the leaves. There it is elaborated, assimilates the carbon taken from the carbonic acid of the atmosphere, is concentrated by a considerable evaporation of water, then, descending, is distributed through the plant, producing a growth of these various organs. We know that this transpiration by which plants lose a portion of the water they contain takes place during the heat of the day, and that it is greatest in proportion as the atmosphere is dryer and the soil most saturated with water. Moreover, this evaporation can never be decreased for any species of plants beyond a certain limit. It becomes, however, enormous under the combined action of the dry wind and sun. Physiologists estimate, approximately, the daily evaporation as being one-half the weight of the plant. Thus, according to this estimate, one hectare of cabbages (4,471 acres) may lose 20,000 kilograms (44,000 pounds) of water during the twelve hours of the day. It is easily understood that the general activity of vegetable functions is in proportion to the abundance of transpiration, but only on condition that the soil is able to support the afflux of sap caused by the incessant consumption of water. As soon as the humidity of the earth becomes insufficient, the current diminishes and the plant remains inactive. It is true that transpiration has also diminished, but it can not be altogether annulled; so that if the quantity of water restored by the soil continues to diminish the plant withers, dries up, and finally dies.

THE NEED OF DRAINAGE.

Dennis C. Crane, secretary of the Union County (N. J.) Board of Agriculture, in 1889, made a report, in which he argues for underdraining and irrigation. He brings up the whole question of water management when referring to the damage done by excessive rains. "There is no way of insuring," he says, "against loss * * * so certain as underdraining. By surface ditches it is only partial and not lasting." Mr. Crane declares that two-thirds of the land in his country requires such drainage. The effect is to not only carry off the surface water, but to warm the land, facilitating the working thereof, keeping the surface from being washed, but it also enables the land to better withstand the effects of drought. The soil's nutrient qualities are retained. Mr. Crane, in connection with the effects of drought, presents this argument in favor of irrigation:

> In a dry season everything everywhere is parched and sickly; then the farmer or gardener wishes he could utilize the abundant supply of water under the surface 20 or 50 feet, or the brook not far off, which is running to waste. Drought can be very much mitigated by deep plowing, thorough cultivation, high manuring and mulching, and the inducing of a rank growth early in the season in order to shade the ground.

These are some of the simple, but not always effective, methods. Moisture has two offices: one to give sap to the plant and the other to make the ground soft, so that the fibrous roots can penetrate and reach out for food. To lose a crop by drought is no small loss, especially if it be garden vegetables, fruit, or even general farm crops. Often from $20 to $100 is spent on an acre for plowing, planting, cultivating, and the use of the ground. The crop, if saved and sold, might yield double the above amounts. In every dry season an extra price is usually realized, so it becomes the farmer to study whether he can not, by irrigation, insure himself against drought.

Irrigation necessitates underdraining, for water can not stand on the surface and stagnate. Irrigation is practiced largely out West and in other countries, and why might it not be adopted here by many farmers and gardeners? Those who have streams of water running through their farms might, by a simple, inexpensive method, raise the water to such a height that it could be led to flow over their fields and in a dry season increase the crop a hundredfold. The saving of one crop would often pay for the original outlay.

Grass, especially, responds generously to such treatment. Many places have basins between small hills that could be made reservoirs and filled with water during the rainy season.

THE RIVER SILT AND ITS VALUE.

The importance to cultivation by irrigation of the silt carried by streams to land where the water is to be distributed is a matter that can not be too vigorously emphasized. All hydraulic engineers and irrigation cultivators, except the professional directors of Anglo-Indian works, are in favor of utilizing the silt for fertilizing purposes. The French authorities, de Cossigny, Mangon, and others, are emphatic in favorable argument and illustration. Professor Lyell, the illustrious geologist, taking the experiments of Everest on the waters of the Ganges as a basis, has calculated that this river bears annually to the Indian Ocean quantities of mud of extraordinary fertility, the weight of which would be equal to six times that of the largest pyramid of Egypt, which is higher than the cathedral spire at Strasburg, and three times the height of Place Vendome column. M. Hervé Mangon says that—

> The mud carried off by the rivers to the sea is either taken from the lands under cultivation or from the surfaces of denuded territories. In the first instance, agriculture, in not arresting this mud, allows a part of its domain to escape, thus losing the most valuable part of its capital; in the second instance, she fails to take possession of that which nature so generously places at her disposal.
>
> The weight of the mud drifted by the Var during one year would form a volume of 12,222,000 cubic meters, which would be sufficient to colmatage more than 6,000 hectares to a thickness of 20 centimeters. A small lateral canal carrying water from the Var, properly planned and carrying only one cubic meter of water per second, could colmatage every year to an average thickness of 50 to 60 centimeters ten hectares of sterile soil, and, consequently, create each year a value of 30,000 to 40,000 francs.
>
> If the weight of the drifted mud be added to the weight of the soluble matter * * * it must be remembered that the Seine carries away, under our eyes and without our noticing it as it were, 2,117,984 tons of solid matter every year, a weight nearly equal to the whole of the merchandise transported over this stream to Paris (Agricultural Hydraulics, M. de Cossigny, Paris, 1889, pp. 27, 28).

The utilization and value of this material is constantly and strenuously insisted upon by all European authorities on irrigation. The works of leading French writers and scientists, Messieurs Cossigny, Poyen, Deville, Mangon, and Buffon, are full of illustrative discussion of this problem. Mr. Hervé Mangon, for example, states that the river Durance, an Alpine stream, largely availed of for agricultural purposes, carries annually with its flood a volume of not less than 11,000,000 cubic meters of silt, the fertilizing power of which is equal to 100,000 tons of stable compost or excellent guano, fertilizers full of nitrogenous qualities. This volume of silt contains as much carbon as would 119,000 acres of forest trees. The Var, carrying to the sea, as M. Mangon estimates, not less than 12,220,000 cubic meters of silt, also bears off in it at least 23,000 tons of azote or nitrogen.

Water carries with it as it flows something of all the mineral substance it touches. Rain dissolves the potash in granitic soils and the phosphates in those of a volcanic character. Care is needed, as it sometimes happens that more mineral matter is thus held in solution than is necessary for the crop. The rule, however, is the other way. River water has been found to contain potash in considerable quantity.

The famous artesian well at Grenelle, France, yields water affected by potash. As an example it may be stated on the authority of M. J. Charpentier de Cossigny (Agricultural Hydraulics, Paris, 1889) that a hectare (247 acres) of land receives in six months, under the French plan of irrigation, about 49,600 cubic feet of water, which contains nitrogenous matter equal to 98 tons of stable compost. At Paris the same authority, quoting Deville, estimates that every 3 quarts or liter of water precipitated, contains at least 43 grains of ammonia. The nitrogenous material that runs to waste is, therefore, enormous. Every drop of water contains it and the poorest of river silt is more than equal in fertilizing qualities to the best of stable compost.

The word "colmatage" is necessarily coming into use in connection with irrigation work and an explanation is in order. It signifies a method of raising lowlands by the deposit thereon of river silt, ooze, or mud, which has long been used in Italy and more recently in France. The Italians call the operations carried on by them on the banks of the Arno, Po, and other rivers, "una colimatu," which means "filling up." Mr. Nadault de Buffon has made a new word, "colmatage," which has already become incorporated in the French language and is now coming into use as a technical phrase among English-speaking experts. The deposit of mud or silt on the same piece of ground very quickly acquires a remarkable consistency, especially if the water be freely applied. This plan may be still further pursued. A piece of ground may be submerged by the muddy waters of a river, letting the water continue to run after depositing the mud, and then repeating this operation several times. A substantial soil will thus be created, which will be susceptible of the highest degree of culture, at the same time raising a low-lying piece of ground and transforming the area subject to frequent inundations into one much better adapted to cultivation. This is what is understood by "colmatage." This process has been suggested as a means of beneficially utilizing the "slickens" or débris of the now abandoned hydraulic gold mines of California. This débris became so injurious to the farmers of the San Joaquin and Sacramento valleys by reason of its being deposited in the sierra river beds and thereby causing overflows, that such placer mining was stopped by law. It is now found that the "slickens" can be flumed onto the low tule or marsh lands and be made valuable by creating new soils and new farms.

By all these processes the intrinsic value of the matter contained in the water courses is, by means of irrigation, placed, in a great part, at the disposal of agriculturists. But after all, the value of the fertilizing matter contained in the water is but a small percentage of the value of irrigation, which consists principally in the marvelous effects of the judiciously combined action of the water and the heat. Water assures the efficacy of manure, so that when the application of a fertilizing substance will not produce a sufficient increase of products to pay for the expense of applying it in an unirrigated soil, as soon as the same soil is irrigated this state of things is changed, and a large interest is realized on the amount expended.

THE INFLUENCE OF LIGHT AND HEAT ON VEGETATION—IMPORTANCE IN IRRIGATION.

This is as important as the absorption of nitrogenous materials. A German chemist and writer, Dr. Hellriegel, declares that the stock of nitrogenous matter "at the disposal of a plant is capable of being assimilated only when a given quantity of heat and light is simultaneously offered." At a point lower than the "optimmum temperature," as Dr. Hellriegel terms it, sluggishness of circulation prevails. With the increase of both factors the energy rises to the life point, which is placed between 64 and 104° F. (20 to 40° C.). Heat up to 122° F. (50° C.) is not destructive, though not as desirable as the lower degree of temperature. Above that point it is considered injurious to highly organized plants. Light operates with similar results. The germinative process goes on best in darkness, following in that of course the lines of all natural action. But the seclusion of light from growing plants prevents the formation of leafgreen (chlorophyl) and of all that aids the decomposition of carbonic or carbon dioxide. The assimilation of light into the leaf cells is absolutely necessary to plant growth. Faint light and persistent cloudiness makes feeble the circulation. This increases in intensity with the rise to "optimmum." All these conditions are found in favorable relations within those sections of the United States where irrigation is needed for security or absolutely required to insure cultivation. The lowest point of field germination as to heat is from 32 to 41° F. (0 to 5° C.). The process of respiration in the plant is the one requiring the least amount of light, but the effective assimilation of carbon, so essential to the health of the plant, requires both heat and light. As the vegetation approaches maturity it requires a large degree of both. So it appears that the quantity or range of mean temperature is the measure of productiveness, water and soil being both considered. With irrigation then the dry, warm air of the arid region bears the palm. Heat, light, and water are prerequisites of successful agriculture when brought to and combined with the soil in appropriate conditions and quantities within the laboratory of the earth. The power of heat transmission combined with the transparency or clearness of the atmosphere which is so remarkable a characteristic of arid regions, is another condition of the highest importance to all plant as well as other life. It is shown that "the diathermancy and transparency of the air are both of the very highest importance to the life existing upon the earth. It is its diathermancy which enables the sun's heat to reach the terrestrial surface for the performance of its marvelous operations. It is its transparency which renders the air the window of the earth, giving man his outlook into space, and admitting the wonderful effects of color and light. If the air were not transparent, all nature would be in a perpetual dense fog."*

The same authority presents some figures which forcibly illustrate atmospheric influences on plant growth. Condensing the phenomena presented, it is found that air has weight, a cubic foot turning the balances at 573.5 grains, while 13 feet respond to one pound in weight. Its particles or atoms are so small as to be invisible even under the microscope. Being in the gaseous state they are compressible, and by a pressure of 15 pounds to the square inch air is reduced to half its previous bulk. It has been established that every time the pressure is doubled, the volume of atmospheric air is halved. This is the reason for rarefication at high altitudes. But heat also expands it at "the rate of $\frac{1}{489}$ part for each degree Fahrenheit. The atmosphere is composed of two gases, which mingle without pressure. "Each is, as it were, a vacuum to the other." Aqueous vapor then rises to and is held in the interspaces in a similar manner, but more may be sustained in suspension in warm than in cold air. There is besides the aqueous vapor "3.36 parts in every 10,000 of carbonic acid gas, and 3.5 to every 10,000,000 of ammonia." Every 1,300,000 tons of carbonic acid produces 377,475 tons of carbon for the air that rests upon every square mile of the earth. Of ammonia 30 pounds are carried down each year by rain to each acre on which it falls. A small quantity of ozone is also formed under the operations of atmospheric phenomena. The barometer rises when the air is overcharged with vapor; when that is condensed the barometer falls and rain is produced. For that reason when warm air drinks up the moisture, it rises rapidly and is carried to an altitude when a change of atmosphere brings about condensation and it falls again. Thus the mountain tops become condensers of moisture. These simple items of physical data are presented only to emphasize the conditions which tend, whenever irrigation is practicable in a region without the industrial mean of precipitation, to make agricultural reclamation by the artificial conservation, conveyance, and distribution of water a process so secure and effective to captivate the brain and energies of all who pursue its practice.

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* Scientific American Supplement. "Physical properties of the atmosphere." Marriotte and Boyle.

ALKALI AND IRRIGATION.

The treatment of alkali soils, which are so prevalent in the West, is one of the serious problems of reclamation by irrigation. The salt-impregnated earth, black or white in character, requires leaching and aërating; also systematic draining. It needs sometimes the application of neutralizing fertilizers. Irrigation by flooding may generally appear to remove this evil, but it will be found that leaching and aëration may not prove permanent curatives. The alkaline salts, washed from the surface, are seldom wholly carried away, and in fact, especially by flooding, are seeped into the soil and carried down, to often reappear again on the surface, especially where indifferent farming and waste of water will leave the same unduly wet or allow the forming of puddles, pools, and standing bodies of shallow drainage or phreatic waters. The most effective, remedy, then, in addition to leaching and aëration, is that of sub and deep drainage, especially the former. The adaptation of plants to alkali soils needs to be closely studied. Wheat can often be profitably sown; forage plants also, especially alfalfa, which has in a great degree the qualities of neutralizing the injurious salts. Root crops, carefully selected, are also excellent aids in the eradication of alkali. The best are beets, rutabagas, mangoes, which take from two to three years to absord the salts, but they do it quite effectually. Sugar beets are more rapid, but the first crop used on alkali soil is of no value. Potatoes and artichokes can both be used on small areas, but they are not so efficient as the several beet roots. Irrigation farmers who expect the water to do all the reclaiming are sure to be disappointed. The application of "land plaster" or sulphate of lime, in combination with stable manure, by which sulphate of ammonia is produced, is of great value in eradicating black alkali. The white alkali earth is less noxious or injurious. In dealing, then, with alkali soils the irrigator must leach or wash them well; plow deep and pulverize thoroughly; then prepare, if the conditions demand, for both sub and deep drainage. With these in hand and proper use of land plaster and special crop planting, he may, nay, nearly always will succeed in reclaiming land, which, irrespective of the alkaline salts in it, is generally very rich and remarkably productive. Such reclamation is seldom or never a problem beyond reasonable solution.

In chemistry the alkalies belong to the class of caustic bases, such as soda, potash, lithia, ammonia. These are the alkalies proper. The alkaline earths are magnesia and lime. Magnesia with oxide and other compounds of iron with oxygen belong also to the class of insoluble bases. The principal compounds or salts of alkali, which are formed by union with acids, are the sulphate and carbonate of soda (glaubers and washing sodas) andchloride of sodium or common salt. In smaller amounts, but not always, are found also, sulphate of potash, phosphate of soda, nitrate of soda, saltpeter, and carbonate of ammonia. These last five are recognized fertilizers. The "black alkali" results from a combination of carbonate of soda with black humus, or vegetable mold, and in this way is formed the most injurious of alkali soil. It can readily be recognized when dry by the dark rings left on the margin of places formerly wet. The white alkali is the result of the combination of the glaubers and common salt; the alkaloids are from the bases named, formed and found in many roots, such as the sage brush and other indigenous plants of the arid region.

The cropping out of alkali on lands under irrigation is due largely to the almost reckless waste of water common to earlier irrigation efforts. The evil effects of waste by undue flooding, by standing surface pools, and by the sideway seepage or soakage from canals made through porous soils, the effect of which has been to raise the phreatic plane or table, thus bringing again to the surface the alkali which was soaked and seeped in on the first floodings that followed the use of irrigation, are now being greatly mitigated in California. E. W. Hilgard, professor of agriculture in the State University of California, and director of the state experimental station, is doubtless the best American authority on the subject of alkali soils and waters. He does not consider the presence of alkali an unmitigable evil, and under some conditions and to certain crops thinks it is even of advantage.

In dealing with this evil it must be borne in mind that when water sinks only vertically, by reason of its hydrostatic pressure, it causes the ground water plane to rise at remote points, and forces moisture to the surface which does not necessarily come directly from an irrigation ditch, but which may have been a component part of the ground water for years past. Water thus permeating, and at times saturating, the soils that are rich in salts, ordinarily classed as alkali, are sure to dissolve more or less of these salts, and it will retain them in solution until sooner or later some portion arrives at the surface and there evaporates. Though the quantity of salts in solution may be very small and imperceptible to the taste, yet the effect on the soil of the continual upward motion of water is ultimately sure to become apparent. At the surface the soluble salts are deposited, and at the surface and in the surface soils there will be a gradual increase of mineral salts. The white efflorescence so frequently making its appearance on alkali soils, at the commencement of a long dry season is directly due to this cause, whether the upward moving water be supplied artificially or otherwise.

It is evident that the alkali of surface soils may be variously affected by rains according to the amount of rainfall and its duration. A light rain which wets the ground only to a depth of a foot or two may dissolve the efflorescence and all alkali crusts on the surface and carry the salts back into the soil. Some of them will return to the surface in the course of time, when the moisture returns and is evaporated at the surface. A long, continued steady rain may send a large amount of water vertically down through the surface soils to ground water. The salts leached out of the surface soil will pass into the ground water, and may perhaps be carried off to some other region. A sudden heavy rain, on the other hand, may dissolve the salts on the surface, and flowing in depressions, creeks, and sloughs carry it into streams that flow to the ocean. Only in the latter case is there any certainty that the alkaline salts carried off have been disposed of permanently.

The simplest remedy for such evils suggested by their cause is to secure a preponderance of the downward motion of the moisture. If this can be done more of the salts leached out of the soils by water will move downward away from the surface than upwards toward it. The quantity of alkali at the surface where it is most injurious will necessarily be decreased. The remedy will be made still more effective if under drainage is resorted to, *i. e.*, if the water descending to the subsoils through the surface soil be in a large part carried off into natural channels.

The downward motion of water can be secured by copious flooding. Ordinary flooding may prove an injury instead of a benefit, because in case of ordinary flooding the soil is wet to such slight depth only, that capillary attraction and the hydroscopic properties of some of the alkaline salts cause a return of all or nearly all of the water that has been put on the surface, and it comes back from the saline subsoils freighted with more alkali than it carried down to them.

By flooding copiously and draining off the water from the surface of the land into natural drainage channels, some of the salts can be permanently disposed of, but too much reliance should not be placed on this method of getting rid of alkali, because the process of flooding affords ample time for the water which wets the surface layers of soil to dissolve the salts and carry them into the ground, where they remain, while only the water which holds the least salt in solution is drained off from the surface.

Flooding and surface drainage is for this reason an imperfect remedy. Deep plowing always mitigates the evil, because the alkalies accumulated at the surface are turned under and, as is well known, the alkali at the surface has the greatest power to do harm to tender stems of young plants. By frequent tillage capillary attraction from the surface downward is interrupted and the amount of moisture reaching the surface to be there evaporated is diminished, consequently the amount of alkali brought to the surface is thereby reduced.

It has been difficult to ascertain with any degree of precision what has been the cost of preparing lands for irrigation and what the annual cost of applying water to the land. As but one method of irrigation has found favor for all the different kinds of crops raised, the variations of cost depend principally on the topography of the surface to be irrigated and the permanency of the irrigation ditches.

Mr. H. Scougall, of Salt Lake City, a civil engineer with considerable experience in British India and the Australian colonies as well as in the United States, in a recent paper suggests that water should be sparingly used in irrigation where there is any danger of the appearance of alkali. This advice should, as a rule, be followed under all circumstances by all irrigationists.

Sub-drains from 18 to 36 inches below the surface are the best means of removing alkaline and surplus waters. Deep open drains are also of importance, but successful irrigation in general farming will be found to require subdrainage. There is another possibility to be considered as to the value of such a system. All waters which have passed over growing crops obtain thereby an increased amount in solution of nitrogenous material. Their return by drains to the chief irrigation supply may very often prove of value as a factor in fertilization; the more so that all drainage carries with it nitric acid and potash, while losing most of the injurious salts the alkali land has held.

To ascertain the presence of carbonate of sodium there are several tests that may be applied by any farmer. Standing water in low alkali spots has a dark brown tint. It will turn turmeric paper dyed yellow to a brown, or blue litmus paper to a red tint. Gypsum water will detect the presence of carbonate of sodium in any suspected water to which it may be added. Gypsum is excellent as an anti-alkali, where carbonates and borates are detected. Lime, well harrowed in, is also of value. In India the "reh" or alkali is disposed of by leaching or washing it out of the soil affected. The water is then drained or drawn off before soakage can ensue. In both India and Egypt such washing is most successfully done during the winter months. The analogy will probably hold good for a large portion of our arid region. The reason for it is that the water is more clear, and being cold is not likely to sink into the soil. Mr. Scougall's paper states that—

> For three or four years a company has been at work near Alexandria, Egypt, reclaiming the land under Lake Aboukir. The lake itself covers an area of about 35,000 acres and the water is being removed by means of centrifugal pumps. A fresh-water canal has been constructed around the lake, whereby the land from which the water has been removed has been washed. Small dams have been used to retain the fresh water on the newly exposed surface for several days, and it has been found that fresh water will take up 3.5 per cent of salt and become the same specific gravity as sea water. Several acres have been reclaimed and are now under cultivation.
>
> As to India, the evil has long been a prevailing one. In 1760 "reh" existed all along the West Jumna Canal, in the northwest provinces. From 1800 to 1830 the canal was abandoned and "reh" disappeared. In 1838 the canal was reopened and trouble was soon experiened. Since 1838 the Indian Government has constructed several miles of deep drains and limited the amount of water used in irrigation. In addition the natives must now, at least in some instances, pump water from the canals instead of drawing it from head gates, as formerly. This, of course, reduces waste.

The effect of such drainage has been to largely reduce the alkali.

But the methods of treatment of alkali employed in California are of value to the intending and operating irrigator. Professor Hilgard has treated of this at length,* and his views are of such value that, eliminating local references, they are condensed here:

> All regions having a deficient rainfall and requiring irrigation for successful agriculture have tracts of land afflicted more or less with "alkali;" that is, showing during the dry season a "blooming-out" of soluble salts on the surface of the ground. This phenomenon is the direct and inevitable result of a scanty rainfall and a naturally productive soil. The mineral matters required for plant nutrition are being set free by the natural processes included under the general term of weathering; that is, a decomposition of the minerals contained in the soil, among the products of which are always the soluble salts of the alkalies (potash). The potash salts are mostly retained, and form an important part of the mineral food of the plant.
>
> Where the rainfall is scanty, and especially where showers wet the soil only to a light depth, current washing-out can not occur. The sodium salts necessarily accumulate in the soil, together with those of potash, lime, and magnesia, which usually are wholly or in great part retained by the soil. Each time, then, that the soil moisture evaporates between showers it carries with it to the surface in solution whatever of soluble alkaline salts may have accumulated within the depth to which

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* Experimental Station Bulletin, California, No. 83, pp. 140–144.

it penetrated, to be again washed down by the shower to such depths as its amount may justify. This process is indefinitely repeated with one and the same quantity of alkali salts, diminished only to the extent to which some heavier shower may wash away part of the surface accumulation. Hence the lower ground will, as a rule, show a larger proportion of alkali. Being naturally richer in the fine and easily decomposable mineral powder carried down and deposited by the streams, this low ground will develop proportionately more alkali than the higher land. We often find such lands, and even the river bottoms, heavily incrusted, when the adjacent uplands are practically free from alkali. The richness of such valley lands is in proof.

Alkali salts vary in composition, but usually consist of three principal ingredients. These are, in the usual order of their abundance, common salt (sodium chloride), Glauber't salt (sodium sulphate), and sal soda (sodium carbonate). The latter, when present in predominant quantity, gives rise to what is known as "black alkali," from the fact that the sodium carbonate forms with the humus of the soil a dark-colored solution, which, on evaporation in mud puddles, leaves black rings on the soil and surface. The distinction between the "black" alkali and the "white," consisting mainly of the relatively innocuous Glauber's and common salt, is important, for the effect of carbonate of soda upon vegetation is many times more injurious, not only because of its direct corroding effects upon the root-crown when it accumulates near the surface, but also because, as already stated, it dissolves that highly important ingredient, humus or vegetable mold, and, moreover, renders clayey soils almost completely untillable. The latter effect is seen in the low-lying alkali spots, where the soil in which the clay accumulates is so obstinately caked together as to render it extremely difficult to put in the plow. The heavy intractable clods are most difficult to break up. This difficulty does not exist in the case of the "white" alkali soils; they till kindly, and the only trouble lies in the accumulation of the salts at the surface, in consequence of evaporation, to such extent as to injure the surface roots and root-crown. Carbonate of soda or "black" alkali is converted into the "white" (*i. e.*, Glauber's salt) by dressings of gypsum or land plaster, and the relief thus afforded is in very many cases all that is needed to insure profitable cultivation. It is only in exceptionally bad cases that enough of any of these soluble salts to injure the deeper roots exists in the depths of the soil or within more than one inch of the surface. This surface accumulation is obvious to the eye during the dry season.

Aside from the three most prevalent ingredients of the alkaline crusts, there are always present a number of others, some of which are of fundamental importance to plant life. Their mere presence in the soluble form proves that the soil contains in a more or less insoluble shape, but still accessible to the plants, all that it can retain of these useful ingredients. Such are particularly the salts of potash and soluble phosphates, both of which are very commonly found in the alkaline salts from the heavier soils; while saltpeter, in the form of both potassium and sodium nitrates, is common, especially in the "black" alkali districts. It represents a surplus of the most expensive of the fertilizers which the farmer finds it necessary to supply to his soils in order to maintain their productiveness.

The most obvious mode of correcting the condition of alkali soils generally is clearly to supplement by artificial means the natural deficiency of drainage through the soil, resulting from the scanty rainfall. For, if we once leach out the surplus salts that have accumulated for ages, it will take ages to bring about the same condition of things and we shall practically have put an end to the "alkali" difficulty.

But this leaching out can not be done by putting water on the surface of the land, unless at the same time its *removal after passing through the soil* is provided for; for it is manifest that if the alkali solution descends farther than the subsoil and remains there, ready to reascend so soon as evaporation at the surface calls for it, we shall have done no good. In fact, the inutility of this mode of procedure has been so thoroughly tested in practice, both in California and in India, as to have shown that it is the reverse of useful and increases instead of diminishing the evil, because the soluble salts thereafter ascend from greater depths than the annual rainfall could have reached and their sum total is thus materially increased. This is the simple explanation of what is known as the "rise of the alkali," which is observed in all lands subjected to surface irrigation for some length of time, creating increasing inconvenience and alarm as time progresses.

Underdrainage is the general and absolute corrective of alkali. To flood the land until underdrains, laid reasonable distances apart, shall have run for some time, will end the trouble, not only for the time being, but for centuries, provided only that solid beds of the alkili salts do not underlie it. But this is the rare exception.

There is, however, in certain regions one difficulty in the way of the success of this operation, namely, the existence of a bed or layer of calcareous hardpan, equally impervious to roots and water. Farmers have already learned that where this hardpan underlies the subsoil at a few feet depth trees and vines will not flourish unless it is broken through, so as to enable the roots to pass beneath.* This "knocking the bottom out" of the holes in which trees are to be planted has already become a well-understood operation in the hardpan neighborhoods, the crowbar, or even a charge of powder, being called into requisition. It is noticeable that in such localities the alkali plague comes soonest and is most persistent, being the natural result of the retention of the alkaline water above the hardpan layer, and its reascent, with all its salts, so soon as evaporation sets in. The obvious remedy in such cases is to make the drainage-ditches deep enough to cut *through* the hardpan and to knock so many holes into the latter as to facilitate drainage to the necessary extent. And where the land is otherwise suitable to special crops, such as fruits, the irrigator will always find underdrainage a paying investment.

In reference to gypsum as a remedy, Prof. Hilgard says:

> It is apparent that, so far as the efficacy of the use of gypsum against alkali is concerned, each region will have to determine for itself whether or not its alkali is of the black or white type; and as this can be generally readily ascertained by a simple inspection of puddles on alkali ground—whether or not tinted by the dissolution of the vegetable mold into an inky liquid, leaving black rings on evaporation—no one need be long in doubt on that point. Wherever the black tint appears, dressings of land plaster, ranging from 200 to 500 pounds per acre, will usually effect the change from "black" to "white," after one or two irrigations followed by cultivation; preventing the killing of seeds in the ground as well as the dwindling of seedlings after sprouting, and greatly improving the tillage of the heavier soils. Thereafter, the chief measure toward the prevention of the rise of the salts to the surface is whatever tends to prevent evaporation from the land surface; and therefore particularly the maintenance of deep and thorough tilth and the avoidance of the formation of any surface crusts. These means, together with a proper choice of crops and mode of culture, will serve to maintain good production in most cases until the radical cure by *drainage alongside of irrigation* shall be justified by the increased value of the land.

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* Such a danger may be found in Southwest Idaho in the otherwise rich region of the Boisé and Fayette valleys, where a volvanic hardpan is found.

THE PHYSICAL CONDITIONS
AND
PROGRESS OF IRRIGATION.

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Rio Gila Valley and Unreclaimed Land near Yuma, Arizona.

IRRIGATION IN STATES AND TERRITORIES.

ARIZONA.

The messengers who brought the news of the "land of promise" were ridiculed. Their report was doubted because of its very truth. The ruins that mark some of the valleys of Arizona and the lines of prehistoric canals that still wrinkle their surface tell of the life that has been and promise nature's bounty to future irrigators. Even in its arid expanses the traveler remains entranced. After entering the Territory, mountain walls tower around him at every step, which the constant sunshine paints with vivid tones. As he proceeds into the settled portions, the luxuriance of the tropic growth is encircled by the desert cactus, and gardens of magical beauty dispute the land with the fantastic vegetation of an arid desert. In a little while, however, the irrigator lengthens his ditches, and the gold and green of harvest overspreads the face of nature. For the last quarter of a century the growth of the Territory has proceeded by small but sure degress, the population following the lines of the canals; and each year sees a new, if small, area brought under the dominion of man. In this struggle it is interesting to note how closely the modern cultivator has traversed the canal lines of the elder agriculture. In the Salt River Valley a map will show the present ditches, sometimes in the beds of the old water ways, but never diverging to any wide variance. It is doubtful, indeed, if the Mésa City Canal would have ever been built had not an old rock cut been discovered, by which great labor and expense was saved the early settlers. The reclamation of Arizona is simply the repetition of history. A portion of the country once supported a populous life.

The modern records of precipitation, as analyzed by Lieut. Glassford, of the Weather Bureau of this Department, show that there is sufficient water if properly distributed and applied to support a greater one throughout the Territory. It is of interest to note that while many remains of a once widespread irrigation system are apparent, there are no evidences of high storage or artificial lakes. Certain theorists, however, have determined that the future of Arizona lies in the construction of enormous storage basins to hold the storm and winter water; yet practical experience is demonstrating that the success of a general system of reservoirs in Arizona may be very doubtful. The amount of sedimentary matter carried down the cañons of the Gila, Salt, and tributary streams is enormous. The problem of storage has another difficulty in Arizona, for bed rock seldom comes within many feet of the river or stream surface; and it is doubtful if many reservoirs could be constructed that would not either fill with detritus, silt, and sand, or be able to resist the force that may wash out its dam during a spring flood. The flood of February, 1891, washed away a stage station at Phœnix that had been built since 1858. According to the observation of several local engineers, if that flood had been restrained sufficiently to deaden the force of its water it would have deposited enough matter to bury the city of Phœnix 200 feet deep. The débris traveling in the water wore iron bolts 3 inches wide and $\frac{5}{8}$ inch thick down to a feather edge. Iron nuts were worn off, and 4-inch planking was reduced in size to 1 inch. The problem of storage has been carefully considered by the local irrigators and inquirers, and abandoned for the present as too costly for the resources of the community and dangerous. Dams in the beds of torrential streams are never likely to stand the tests required for security.

Under the present irrigation system two and three crops per year of the staples can be raised. Vegetables, such as celery, tomatoes, and beans, and fruits like melons and strawberries, can be raised during the winter in the open air. The slightest irrigation will suffice for these crops, and in the season water is abundant in all the streams, and is supplemented by rainfall in the valleys. The orange, the grape, and the fig need the heat of the ever-bright summer, but every month in the year has its crop. The Chinese raise enormous quantities of vegetables during the winter on very small areas, the only limit of production being the market, which, on account of incomplete railroad facilities, is practically confined to the farmers' immediate neighborhood.

Under the direction of Congress the United States Signal Service has prepared a series of able monographs upon "Irrigation and Water Storage in the Arid Region." The experience of the writers therein in connection with the Weather Service gives to their views and conclusions the weight of expert authority. In this place it will only be necessary, as part of the review of progress that belongs to the irrigation inquiry, to briefly refer to some of the chief conclusions they have reached. Lieut. Glassford, whose knowledge of our southwestern region and its climatology, is most extensive and accurate, says in his report on Arizona:

> In general it may be said that the question of the reclamation of any arid land presents itself for discussion under five topics, which it is well to note. They are: (1) Geography and hyetophysics of the region; (2) amount of land which may be irrigated; (3) amount of water which may be used for irrigation; (4) economy of irrigation; (5) legal questions involved. The lines of division between these topics can not be sharply drawn; each involves consideration from several points of view and thus comes within the province of several studies.
>
> The economical and legal questions are to be settled by the intending investor and his advisors; the amount of land and the amount of water available for use upon it are to be determined by engineers; the meteorological student may in pursuit of his researches find himself involved in the discussion of any or all of these topics, but his special province is the hyetophysics as affected by the determining facts of nature.

As a matter of course the chief importance of the papers under consideration consists in their precise and able review of the climatological conditions affecting and controlling aridity. It is therefore of importance to present as briefly as possible the salient factors in such reviews. Lieut. Glassford discusses Arizona, New Mexico, and California. Practically also, the State last named indicates the chief elements of the problem of aridity in connection with Western Nevada, and the eastern portions of Oregon and Washington.

To begin with Arizona then, Lieut. Glassford says, with the special agent in charge of the irrigation inquiry and all other authority on the subject, that the study of hyetophysics, or of the original search for the causes of climatic laws and effects, must be the first one made. The farmer, the investor, the engineers appreciate the existence of the rich alluvial bottom land, and of the fertile areas embraced by the table or mesa portions of the topography. The reclaimability of these areas is within their province, but in order to work most intelligently they must be in possession of the data. Mr. Glassford states with force that—

> The origin of every grain of humus in the lower rivers is to be found on the jagged mountain peaks, on the bare plateaus, and in the eroded cañons of the central and northern portions of the Territory; the origin of every drop of water that flows to waste upon the shoals of the Gulf of California, of every inch of water that by wise forethought has been applied to the moistening of a soil, so rich as to need no reinforcement of artificial fertilizers, must be sought in the winter and summer rains, in the lingering mountain cap of snow, and in the destructive suddenness of the so-called cloudburst.
>
> These are the elements of the problem, which must be presented briefly and succinctly in order that it shall be clearly appreciated from the outset, that:
>
> (1) The causes which have produced the alluvial bottom lands are of continual and present operation, and are to be counted on to restore all waste, whether it be the molecular loss of soil washed away as detritus or the chemical waste of soil depauperated by the growth of crops.
>
> (2) That these causes must be accepted as constant factors, not to be altered or avoided, but whose actions may be diverted to channels which shall aid rather than retard the enterprise of human industry.

It is unnecessary to present the review of physical geography which follows, further than to say that Arizona "presents the problem of rain catchment, water storage, and economical distribution, together with notable reclaimability of the land to be irrigated, in terms of almost ideal simplicity."

The trend or axis of the mountain system is well defined and distinct. It runs mainly from northwest to southeast. In the subsidiary range the same axial trend is apparent, and the whole formation indicates the controlling forces which affect the aqueous conditions of the atmosphere, pointing directly to the Southern Pacific Ocean, its currents and winds. Mr. Glassford says:

> In passing it is well to note an important result of this uniformity of the mountain axis carried out constantly over more than 500 miles, and one which will receive more extended consideration in its proper connection, and that is that the prevalent moisture-bearing wind is from the southwest, at right angles to the broad side of the mountains, and thus encounters the maximum bluff surface. In other words, the passage of the rainy winds across Arizona is by no means an easy gliding over an inclined plane, but the laborious ascent of a flight of steps.

He makes use of a striking comparison by presenting the main formation as "the continental V." This begins in Arizona at an altitude of 3,000 feet, and is not one merely "of contours and rock masses."

The line of 3,000 feet "marks with equal distinctness an important difference in the soil, an astonishing difference in climatic features, and so great a difference in commercial and economical value that it at once suggests the idea that nature has here balanced means with end. The partition is unequal southwest of the dividing line, roughly speaking. One-third of the Territory lies below the level of 3,000 feet. Northeast of the same line two-thirds of the Territory is a lofty plateau. The plan has the fertile soil and the minimum of rain. The plateau receives abundant rain upon its rocky surface and retains almost none of it. The plain is the garden. The plateau is the reservoir of water and the storehouse of life for the soil."

In the area thus indicated, "save a small number of exceptional instances, whose acreage is inconsiderable in comparison, the plain thus defined contains the lands economically available for reclamation."

More than half the Territory "is measured above the 5,000-foot contour," and forms in general what is known to geographers as the Colorado Plateau. To the eastern extremity thereof, and within New Mexico—that is, the plateau or table land of the Raton Mountains—there is in progress a remarkable development of irrigation, the success of which, already quite well determined, may indicate the possibility, even probability, of extending the area of irrigable reclaimability over a vast region heretofore wholly given up to sparse cattle grazing and sheep husbandry. At any rate there is reason to hope for an association of arable and pastoral industries through both open water storage and phreatic supply, by which small areas cultivated for grain, roots, and forage may sustain larger ones brought under fence and use for stock breeding and raising purposes; so that cattle farms rather than ranches will be the order of the near future.

The river systems of Arizona are two. North of its great divide is the Colorado, approximately controlling one-half of the Territory. It has but a small number of affluents, which however are sufficient to carry off the scanty rainfall. South of the great divide is found the more important watershed (from an irrigation point) of the Gila and its tributaries. Of the plateau divide it is said: "North of it the rivers flow for the most part in deeply-eroded cañons. South of it are level valleys and basins which it is clear have in recent geologic time contained immense inland seas of the order of Lake Bonneville, or the similar region immediately to the north."

One difficulty in the study of "precipitation phenomena" in Arizona, as well as elsewhere in our mountain region, arises from the fact that the stations for meteorological observations are for the most part in valleys and cañons. The heavy rains occur on the high altitudes. While in the lower Gila and Salt River valleys the annual precipitation seldom exceeds 7 or 8 inches, and is often much less, it is a matter of constant observation by the traveler that the proplateaus, the table land, the mountain slopes, and the overtowering summits and peaks may be black with storm and every arroyo or channel be filled with a torrential flow. "Nor," says Mr. Glassford, "is this confined to the mere sight of showers which go unmeasured. During the winter the most casual observer of the streams sees periods of high water amounting at times to turbulent flood, which are so little to be accounted for by the record that the conclusion is irresistible that existing records indicate only a fraction of the actual precipitation which can be relied upon for water storage, and that these data represent perhaps the minimum quantity of the rainfall. Yet, despite this known disproportion of the recorded and actual efficient rainfall, it has," says Mr. Glassford, "been shown that the measured amounts are sufficient to supply water for the irrigation of much more land than the acreage known to be available."

This last statement is of value as contrasting with another made in a bulletin of the United States Census to the effect that with 65,821 acres (the area given as cultivated by irrigation in the fiscal year 1889–'90) there is no more available water "in sight" for the extension of the area of cultivation. The amount of land "under ditch" at the same period is given as follows:

	Acres.
By the Governor of Arizona	587,460
By Mr. F. H. Newell, U. S. Geological Survey	455,000
By United States Senate Irrigation Committee report	529,200
Or an average of	523,887

Mr. Glassford's statement, it will be observed, is that the "measured amounts" of water—and therefore "in sight"—"are sufficient to supply water for the irrigation of much more land than the average known to be available." It must be borne in mind that Mr. Glassford's "measured amounts" of available rainfall does not embrace the "storm waters," the storage of which is the objective point of the agent's limitative remarks in the census bulletin referred to. Mention is made of this difference of view because the same factors exist over all of the arid region in greater or less degree, as Mr. Glassford points out in the paper on Arizona to which reference is now called. The necessity of providing for distinct, definite, and continued weather observations in high altitudes is emphasized by the conclusions presented by the weather service experts. No greater service can now be rendered the practical consideration of reclamation by irrigation than the establishment of mountain observatories and the inauguration of climatological investigation, having specially in view the cosmical laws affecting our Cordilleran water supply.

The division of Arizona into "plain, proplateau, and plateau" serves also to mark the division into two essentially "variant systems of isohyetal curves." The curves of the physical system are the lines also of precipitation and its changes. Both reproduce "the characterizing axial inflection of the mountain mass." The plain has no great elevation or high ranges. Hence its rainfall is not within, to any large degree, the corrective effects required by the unmeasured fall upon higher altitudes, in other portions of the territory. Speaking of the Colorado Basin region around Fort Mojave, Mr. Glassford says:

> Upon this low plain the rain records approximate the absolute minimum of the world. It is from the reports of early travelers in this region, as rainless as the Saharas or the central plains of Australia, that has sprung the common belief that Arizona was agriculturally worthless because of its aridity. Hunters and trappers in search of game, emigrants wearily accepting the desert as the hard path leading to the promised fatness of California, prospectors seeking placers and pockets, had neither time nor inclination to think of aught but the means of protection against the Indians. They found their road lying over sandy plains, where springs were far away and where the sky was seldom clouded with rain. Carelessly they called the land a desert, carelessly their hasty decision spread, and now this prejudice, founded on ignorance and faulty observation, yields but slowly to the argument of facts.

The pro-plateau and plateau sections are associated together in Mr. Glassford's review. The "extensive" high lands thereof exercise the largest influence as "rain-makers." With one exception, too, "the isohyetal curves tend to follow the axial inflection" of the mass. "With sufficiently remarkable regularity the curves of annual rainfall, amounting to more than 10 inches, fall quite to the south of the great divide, and thus indicate for the Gila watershed a considerable superiority of water supply over the Colorado system."

These curves "also draw in water" the division between plain and plateau. The curve of 15 inches is to the southeast and embraces the region drained by the Santa Cruz and San Pedro rivers. The 20-inch curve is also located in southern and central Arizona. The highest curve shows a fall of 25 inches, and "accords with the roots of the San Francisco Mountain" in the northwest.

The seasonal relations of the rainfall are of marked importance. Mr. Glassford says:

> Arizona has two plainly marked rainy seasons, a fact which largely balances the relatively small precipitation. In this, as in every particular of the study of precipitation in the Territory, it should be noted that the physical features are such as to lead all rain precipitation down the steep mountain side, everywhere approximating perpendicularity with such rapidity that the surface which receives the rain is little benefited thereby, and the valleys are almost instantly affected.
>
> The season of winter rains begins in December with a marked absence of precision in definition, but at the other end in February its termination may be predicted within narrow limits. The precipitation during this season is neither so great nor so much to be relied upon as the rains of summer, yet it serves a regulating purpose,

whose direct influence upon the climate and the more particularly hydraulic features now under discussion is persistent for months after the definite conclusion of the season which produced it. The precipitation at this season is both heavy and general while it lasts. The season presents a series of weather types which have been the subject of some study in connection with their annual and secular appearance upon the Pacific coast. In brief, the storms are of the sort conventionally known as cyclonic or low barometric areas, between which are interpolated anticyclonic areas marked by extreme cloudlessness and slight humidity. As in the case of the seasonal rains of California, so in Arizona, the variability of the winter rains in amount and frequency is in the ratio of the intensity and recurrence of barometric disturbances. To this characteristic feature is due the intermittent effect of the rainfall, which gives the streams both high and low water during the rainy season. To such an extent is this tendency carried that in time of drought some of the streams become mere rills, and even disappear altogether, either because of total failure of the source of supply or because the water has sought underground channels beneath the great deposits of detritus, sand, and silt which have washed into the beds of the streams on account of the rapidity of passage of rain water to a distinctly lower level over mountain sides of notably steep pitch.

Despite the fact that the amount of rain precipitated during the three winter months is measurably less than in summer, it never fails to flood the streams. The reason for this has already been indicated in the sharpness of the contours of altitude. The low temperature which prevails upon the plateau during this season also tends to magnify this result. The soil of the mountains, naturally little pervious, is made still more impermeable by the freezing of rains upon it, so that succeeding rains fall upon glare ice and are hurried to the valleys with a minimum of absorption by the soil. Much of the precipitation of the winter rainy season occurs in the form of snow, which is retained upon the spot where it falls. Succeeding falls add to this mantle of stored water until it is by no means unusual to find it on the mountains all the way from 3 to 7 feet deep. It thus appears that the total winter precipitation is naturally resolved into two components, of which one, the rain precipitation, has an immediate though evanescent effect upon the streams, while the other, the snow precipitation, exerts an influence more permanent in proportion as it is less immediate. This mantle of snow is in fact a great storage reservoir with neither dam nor dike, and automatic in its regulation of supply to the causes which avail in producing demand. It remains upon the plateaus of high altitude upon which it has fallen for months after the definite conclusion of the rainy season, and is frequently observed to persist until nearly the beginning of July. Its gradual melting serves to keep a quantum of water in all the streams throughout the dry season almost to the beginning of the summer rains.

The summer rains come in July, August, and September, being somewhat sharply defined from the preceding dry season, but shading so indeterminately toward the beginning of the winter rains that it becomes quite proper to say that, while Arizona has two rainy seasons, it has but one dry season. Although there is no positive delimitation of time between the rains of summer and those of winter, there is to be noted a differentiation of character. The rains of winter are caused by the proximity of approach of great storms in low-pressure areas which form a part of the storm system of the country at large. The rains of summer are local in character and directly traceable to mountain influences, with a distinguishing peculiarity which should be noted for future study. In general the amount of rainfall is greatest in districts toward the point from which the prevailing wind blows; in Arizona the greatest pluvial effort is registered on the leeward side of ranges. A noteworthy feature of the climatology of the Territory is, that when the last snow disappears upon the mountain summits the summer rains commence. So constant and so well appreciated is this relation that the oldest settlers, and the Indians before them have been in the habit of calculating the coming of the rains in accordance therewith.

It has been noted that the summer rains are of local character; they appear somewhat upon the plain, but their maximum amount and intensity is displayed upon the plateau. While their total amount is considerably in excess of the sum of the winter rains, the amount of any individual precipitation is uniformly less than any one precipitation of winter, and the excess is made to appear through the sum of a long series of precipitations, which are of almost daily occurrence upon the mountain summits. They rarely have any great extent, but their intensity is so remarkable a feature as to warrant particular consideration.

The fact that showers are observed almost every afternoon upon the mountain summits, and most uniformly only in the afternoon, points directly to this cause, which may be briefly discussed. A well-established law of atmospheric temperature is that it decreases with the elevation, a law whose operation is easily seen upon snow-clad mountains, where the snow line gradually rises with the increasing heat of summer. During the persistence of the snow the actual decrease in temperature on the moun-

> tain sides is nearly equal to the theoretical decrease with elevation. The white snow surface by its reflection of incident solar heat tends to keep the mountain mass at a low temperature, and possibly such a surface absorbs no more heat than air of the same elevation; at best its coefficient of absorption is small. Thence it results that above the line of actually persistent snow the vertical isotherms may be conceived to differ but slightly over the plateau and over the extensive summits. With the final obliteration of the snow a marked change occurs. The rock surface now exposed absorbs heat and speedily converts the mountains into a radiant body of conical form. The strata of air cut by this cone of radiation and strata lying above it become at once disturbed, convection is instituted, and as the influence spreads over a considerable area, great amounts of air are in a short time lifted to a great height, and in the resulting operations of expansion, cooling and condensation, the upper currents distribute the rain over the plateau and particularly to leeward. By parity of demonstration, the same principles may be shown to account for the diurnal periodicity of these summer rains.
>
> From the foregoing considerations it appears that the rainfall of Arizona, computed on the basis of the present records, whose inaccuracy is known to be subtractive, *is more than sufficient to irrigate the reclaimable soil, great as its extent is known to be* The miximum rainfall of any of the years for which records have been kept is not so great as to burden the usual engineering appliances for handling it, and the possibility of cloud-bursts simply necessitates the construction of stronger retaining works and the maintenance of emergency wasteweirs. The great question to be considered by the engineer in connection with each stream is its hydraulic potential, the maximum amount of water available at the close of the period of minimum supply. That this is sufficient for all his uses is clear from the observations of the meteorologists, of which a summary sketch has here been presented.

Two other factors of importance are treated. These are "evaporation" and the "mechanical equivalent of wind power." The Monthly Weather Review for September, 1888 (p. 235), is referred to as "the first definite step" towards studying evaporation as "an essential climatographic datum." Mr. Glassford states (Irrigation and Water Storage in Arid Region, p. 307) that—

> In general it may be said that the amount of evaporation depends on the dryness of the air, the velocity of the wind, the temperature of the evaporating water, the extent of the evaporating surface, and, other things being equal, varies inversely as the barometric pressure. It is possible also that the amount of evaporation may be reduced by the height of the banks of the reservoir, or, what amounts to the same thing, the lowering of the water level.
>
> Instrumental records were carefully taken at a number of stations in this country between July, 1887, and July, 1888. Four of these stations were in Arizona, and the records of these posts are here presented as they appear in the Monthly Review. They serve to indicate what must be the evaporation from storage reservoirs, since, even though they do not give the actual evaporation from every square inch of water surface (and this is uncertain, it is neither asserted nor denied), yet they supply a proportional scale for the comparison of reservoirs within the same or different atmidometric curves:

Station.	1888.						1887.						Year.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Fort Apache	2.6	3.0	3.6	6.8	9.4	9.1	7.1	6.7	5.3	5.2	4.1	2.6	65.5
Fort Grant	5.2	4.8	6.4	9.2	10.2	13.8	12.4	10.5	9.0	7.9	7.2	4.6	101 2
Prescott	1.4	2.8	3.6	5.4	6.2	8.1	6.6	6.5	4.7	4.9	3.6	2.2	56.0
Yuma	4.4	5.2	6.6	9.6	9.6	12.6	11.0	10.2	8.2	8.2	5.5	4.6	95.7

> Arizona is, therefore, entirely above the line of 50 per cent; one-half is above that of 90 per cent, and one area therein reaches above the maximum of evaporation in the United States, which is 100 inches.
>
> The greatest amount of evaporation occurs in the plain, which is the region where irrigation is destined to be applied, and the curves of high evaporation include nearly all the projected reservoirs. Yet, on the other hand, it should be noted that the enormous amount of evaporation within the 100-inch curve will scarcely affect the economic features, because in the San Simon and Sulphur Springs valleys, over which this curve is drawn with close restrictions, present indications point to irrigation by utilizing the subterranean flow of waters which are below the reach of evaporating influences. (P. 307.)

In relation to wind power, Mr. Glassford has the following paragraph:

> Enormous power goes to waste all over the land in the wind which blows and is not utilized. The question is one which has engaged the attention of mechanicians, who recognize the power latent and find their difficulty, not in rendering it immediately efficient, but in conserving its energy. For irrigating purposes in Arizona this difficulty needs no consideration; it is sufficient to raise water into a tank or reservoir whence it may be drawn as needed. The wind may not be constant, but its direction is immaterial, and the force which will operate a modern wind motor is very small. Such application of power is very clearly indicated for the fertile valleys of the southeastern corner of the Territory, where abundant streams underlie the soil and may be reached by wells not more than 20 feet deep.

The conclusions reached, then, as to the subjects under consideration, are:

(1) Twice each year there occurs sufficient aqueous precipitation in Arizona to reclaim every acre of land worthy of such reclamation.

(2) The coefficient of evaporation, though absolutely high, is relatively so small in comparison with the total fluid contents of the actual and projected storage basins that it may be economically disregarded as a vanishing quantity.

(3) A measureless amount of foot-pounds of available power is daily going to waste in the winds which blow over the land. This power, rendered efficient by wind motors, will suffice to utilize the large subterranean rivers which are known to underlie large areas of rich land.

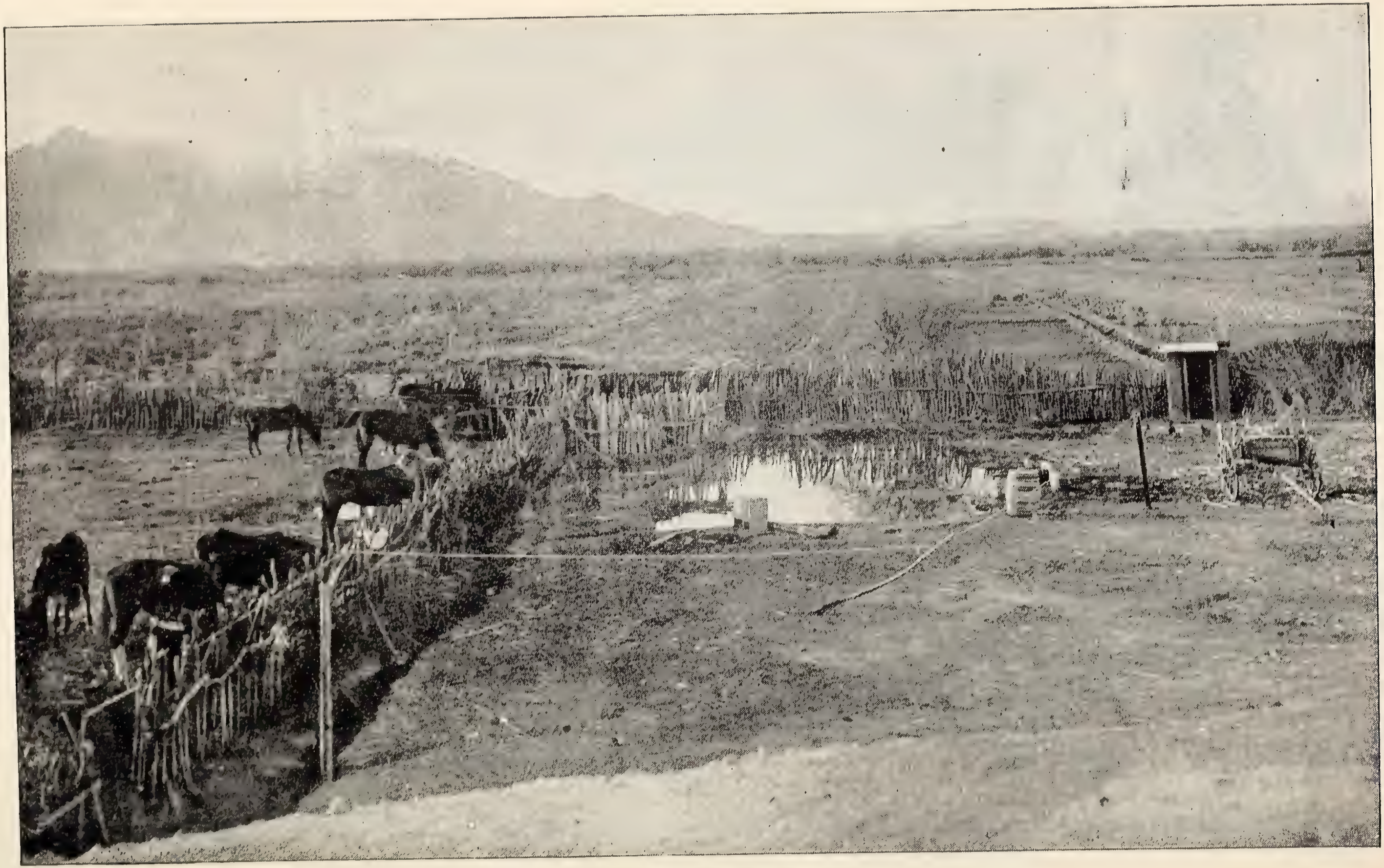
THE SALT RIVER VALLEY.

At present this is the principal irrigated area of Arizona, and obtains its water supply from the Salt River, which heads in New Mexico, 350 to 400 miles to the northeast of Phœnix. The Verde River and a great number of creeks are tributaries to this stream. The Verde heads in the San Francisco Mountains. The entire drainage area is snow-fed. The Salt River Valley main canals are about 300 miles in length, vary from 15 feet on bottom to 36, and are from 3 to 7½ feet deep. There are nearly 5,000 miles of laterals. There are no reservoirs in the valley and but one dam, that at the head of the Arizona Canal, which is 945 feet long and raises the water 8 feet. The area under ditch is 300,000, of which 145,000 are cultivated, at a first cost for water of $10 and an annual water rental of $1 per acre. To clear the land will cost $2 per acre, and to put in grass or alfalfa $5 an acre additional. The irrigation constructions cost from $5.50 to $6 per acre, which cost to the user of water is included in his royalty. The probable average cost to the owners of ditches for annual maintenance and repairs is 60 to 70 cents per acre. Wheat, barley, alfalfa, sorghum, sugar cane, peaches, apricots, prunes, pears, figs, grapes, nectarines, oranges, and lemons, and all staple vegetables are grown all the year through. The average yield is given at the following figures:

		Per acre.			Per acre.
Wheat	pounds.	1,700 to 1,900	Alfalfa	tons.	8
Barley	do	2,200 to 2,500	Sorghum	do	30

The raisin area yielded in 1891 7 to 10 tons of grapes per acre from vines three years old from the cutting.

In other parts of the Territory there are important works constructed, and others are contemplated or under way. The Florence Canal covers 60,000 to 75,000 acres. A canal is now being located from a reservoir at the mouth of Camp Creek, where it enters the Verde, 50 miles northwest of Phœnix, and additional storage for the same canal is contemplated at Deadman Cañon, on same river. It will skirt the McDowell



MOHAWK VALLEY, LOOKING SOUTHEAST. PART OF RIO GILA VALLEY NEAR YUMA, ARIZONA.
One year old irrigated ranch.

Mountains, covering a valley of 200,000 acres, bounded on the east by the McDowell Mountains, north by the foothills lying to the northeast of Cave Creek, and on the south by the foothills lying about 8 miles north of Salt River and to the west of Cave Creek.

A storage reservoir is proposed to distribute the waters of Cave Creek, and a similar project is reported in process of construction on the Agua Fria. Here a dam 1,100 feet long is building across the cañon, from which water will be directed in a southeasterly direction, crossing the Southern Pacific Railroad at Gila Bend, for the irrigation of 300,000 acres. The Walnut dam on the Hassayampa is to be rebuilt.

There are several canals proposed along the Gila, which will cover a great deal of land between Agua Fria dam and the junction with the Colorado. The activity about Yuma is remarkable, and that section promises to grow in prominence for its semitropical productions. One interesting enterprise, which is preparing to irrigate by means of water pumped from the Colorado, will be watched with interest.

During the personal investigation of irrigation in the Salt River Valley, in June, 1891, the special agent was waited upon by a committee of the principal citizens and irrigators, among whom were Hon. N. O. Murphy, acting governor; T. E. Ferrish, ex-commissioner of irrigation; Hon. Chas. D. Poston, ex-Delegate to Congress; Mr. Lincoln Fowler, C. E. W. A. McGuinnis, Mr. Wormser, H. H. Logan, of the Phœnix Chamber of Commerce, and others, who desired to present facts concerning the state of irrigation in the Salt River Valley. They complained vehemently of statements officially made to the effect that only 65,821 acres were under irrigation in the Territory, and 35,212 acres in Maricopa County. The answers to the special agent's questions were taken down by Mr. M. A. Downing, his assistant, and are here given. It is only necessary to say further that the answers were all fully canvassed by the gentlemen present, and in most cases are the results of full discussion.

How many irrigation canals are there in the Salt River Valley?

Mr. FOWLER. In the Salt River Valley there are on the north side of the river the Arizona Canal, the Consolidated, which includes the Grand, and Maricopa, Salt River Valley, and Cross Cut canals, and the Dutch Ditch. All are under one management and form an interlocking system. Farther down the river, on the north side, are the Griffin, Farmers', and St. John's canals under independent management. On the south side of the river the canals are the Highland, the Mesa City Canal, the Utah Ditch, the Tempe Canal, the San Francisco, the Marmonier or French, and the Broadway ditches. The canals on the south side of the river are owned in common by the proprietors of the lands irrigated, but the Mesa City Canal is the only one incorporated by the irrigators. These ditches have numerous extensions and branches, and irrigate wide areas.

What is the acreage under these south-side ditches?

Mr. WURMSER. That can not be given just now, but under the Highland there were eight sections or 5,120 acres cultivated during 1890; the Mesa City Ditch cultivates 8,000 acres. The farms under this ditch are all small. It is owned by the Mormons, and they call 10 acres a farm. The Highland Ditch was taken out to cover land taken up under the desert-land act, and the farms are all large. There are none less than 160 acres. The Utah Ditch irrigates a little over 3,000 acres. These farms are also small, about 10 acres. The Tempe Canal waters

10,000 acres; its full capacity is 12,000 acres. The average size of farm under this ditch is from 160 acres to a section, except that there are some newcomers who raise fruit on plats of about 20 acres each, which might amount to two or three sections. I should say, taking this into account, there are 12,000 acres under cultivation. The San Francisco has 10,000 acres of land under it and carries 5,600 inches of water; there were in 1890 about 4,000 acres cultivated. The French or Marmonier Ditch cultivates 4 sections of desert land, 2,560 acres; and besides this there are 400 acres divided into other small farms. This will make 33,120 acres irrigated and cultivated on the south side of the river during 1890, under the farmer-owned canals.

Mr. FOWLER. Under the Arizona Canal, on the north side, there were, according to the figures of three years ago, 43,000 acres under cultivation; this has increased to a great extent, and in 1890 there was more than that amount cultivated under that canal. There are between 39,000 and 40,000 acres cultivated under other of the canals belonging to the consolidated system, which figures, added to those already given, will make a total of about 116,120 acres cultivated by irrigation in the Salt River Valley, exclusive of the land under the Farmers' and St. John's canals in the lower part of this valley. The estimate of cultivation in the Salt River Valley made by the Phœnix Chamber of Commerce is 125,000 acres. This takes into consideration the increased cultivation under the Arizona Canal systems, and is very accurate up to date.

Mr. LOGAN. We complain of official statements that the maximum amount of land that can be irrigated by the present method of supply has been reached, and that without high altitude storage of water no further advance can be made. There is no storage of water at the present time in the Salt River Valley. Any man who makes the first statement has certainly not seen the country. There is a project for storage, the possibilities of which are very great. But the water in sight will irrigate in the Salt River Valley 300,000 acres. There were in Maricopa County 309,000 acres under canal on the 30th of June, 1890; of that amount there was actually cultivated 45,000 acres in barley, 45,000 in alfalfa, 15,000 in wheat, 5,000 in fruit trees and vines, and 15,000 acres in miscellaneous crops, vegetables, and sugar corn, that make 122,000 acres. There is a large acreage in excess of that not mentioned, most of it being in pasture.

Is it made available by the application of water?

Mr. LOGAN. Yes, sir; I think the pastural area would amount to 30,000 acres. There are a great many fields that are irrigated only once or twice, making too small a crop to cut, but still leaving good pasturage. I know my estimate is conservative. I have gone over it several times with great care, and think I am absolutely under the actual figures. Officials should exercise the greatest care in making statements such as are contained in the bulletin to which I refer. They often do great harm to the communities affected.

Then you say there is 135,000 acres of land under cultivation and use by irrigation and that amount was cultivated on the 30th of June, 1890?

Mr. LOGAN. Yes, sir; but only 125,000 acres was in a state of fair cultivation. Some of our barley, for instance, is in "volunteer;" that is, not seeded, in but coming up from last year's crop. It receives only one watering generally, possibly two, and produces only about one-third of a crop, which cuts down materially our average of production. There are more acres under cultivation in the Salt River Valley than are reported in Bulletin 35. Any man can be convinced, without the necessity of an enumeration, that there are more than 65,821 acres irrigated in Arizona, and I can introduce you, if necessary, to more than 327 irrigators in Maricopa County.

The statements that you are controverting assets that the county of Maricopa had at date of enumeration 327 irrigators, a total irrigated of area 35,212 acres, and that the average size of the farms is 108 acres, with an average value of products of $9.26 per acre. Will Mr. Logan please tell me whether these figures are correct?

Mr. LOGAN. Well, there are cultivated to barley 45,000 acres, which, according to the best statistics obtainable from the thrashers, yielded an average of 1,000 pounds to the acre and 48 pounds to the bushel. That is the average of the whole acreage. I have not the slightest doubt 10,000 acres of barley ran 2,500 pounds to the acre, probably 10,000 acres more gave 1,500 to 1,600 pounds, and the balance went light for the reasons I have given. The average was, however, 1,000 pounds to the acre. Alfalfa produces here under fair cultivation and good irrigation 8 tons to the acre. The average would be 4 tons to the acre, at a minimum value per ton of $4. I believe $3.50 per ton is the lowest it ever reached. In 1890 the average was $4.50. There were in 1890, June 30, 45,000 acres in alfalfa. Of wheat there were 15,000 acres at the same time. I do not know what is the yield of wheat. Do you Mr. Fowler?

Mr. FOWLER. About 120 pounds to the acre.

Mr. LOGAN. There has been less poor farming in wheat than in barley. Wheat is worth about $1.25 per cwt. or 75 cents a bushel. We had fruit for exportation or sale in limited quantities. Probably not over 900 acres of the 5,000 acres planted in fruit in this valley is bearing. I will estimate the value of the first crop at $100 per acre, and think that will be quite conservative.

Mr. WURMSER. It pays more than that. A man here sold and shipped from 4 acres of peaches enough to net $550 clear of all expenses. Arizona is credited by the census viticultural bulletin with having in the whole Territory 1,000 acres of bearing vines, producing 3 tons of grapes per acre, at $16.50 per ton.

Mr. LOGAN. There never were any grapes sold in this country for less than 1 cent per pound. I was offered only yesterday 1½ cents per pound and that is the lowest ever offered. That would make $30 per ton. Three tons per acre is a fair average. I will say, however, that the major part of the vineyards are not in a good state of cultivation. I see that Arizona is put at the head or as high as as any other State or Territory in the amount of grape product per acre, and that is correct. With vines in approximately good bearing, however, I think 4 tons would be the average, but taking it as a whole I think the figures are about right on that point. Grape cultivation in this Territory is mainly confined to Maricopa County; that is, we have nine-tenths of the area. The value of the plant and land, I notice, is put down at $75,000, but the 5,000 acres of fruit in the valley to-day are worth an average of $100 per acre and upward.

Mr. FOWLER. One vineyard sold for $200 an acre. There were about a hundred acres; 80 acres in fruit and 20 acres in alfalfa. Two leading ranches have 200 acres each, 100 acres on both being in figs. The returns for 1890 give the value of the crops as $9.26 per acre in Maricopa County.

Mr. LOGAN. I should think that was below the real figures. A good farmer will get for his barley about $25 per acre, and his alfalfa about

$35 and $40; taking good and bad, one with another, I should think $16 would be very low. In wheat I should say $15. Vegetables are almost all raised by Chinamen, and they do not tell what they get, but I know it goes into high figures; I should think from $600 to $700 per acre. So, taking all kinds of cultivation into consideration, $35 per acre would be a low estimate for the product of irrigated land here.

All of these present, with the exception of Mr. Poston, were, at the date of testifying, practical irrigators, who raised crops. They all said that no one ever took the figures of their farms. Besides, many of them own or are connected with irrigation ditches. They all stated that no request was ever received by them for the figures or statistics thereof.

A further statement is that "the acreage under cultivation may be regarded as approaching the maximum possible with the present supply and methods of use." So far as Maricopa County is concerned, is that correct?

Mr. LOGAN. I do not think it has a shadow of truth. The man who made it never investigated, because we have not one but several canals here capable of irrigating all the land he mentions as now irrigated. I can speak with absolute certainty on that. It is only an opinion and the opinion is wrong. He also gives the limit of cultivation in Arizona at 65,000 acres. The area capable of being irrigated from existing supply works will exceed 2,000,000 acres. In the Salt and Gila valleys I believe there is upward of 1,000,000 acres of land that will come under cultivation from the water in sight.

Mr. MCGUINNISS. I think it will be a great deal more than that.

Mr. FOWLER. I believe the acreage will go away beyond 2,000,000 acres.

You would all agree, then, that 1,000,000 acres would be a moderate estimate of the amount of land that could be reclaimed by the water in sight at this time?

Mr. FOWLER. People who build canals for profit, and have money to invest, have constructed ditches in this valley alone for 300,000 acres, and a further area in the rest of the Territory. These canals are based on the idea of profit.

Mr. LOGAN. The canal system of Maricopa County has cost upward of $2,000,000, probably $2,500,000. From the ditches now constructed we have a supply for 300,000 acres of land, and with further economy it can be made to serve much more. As the land comes under cultivation from year to year a smaller amount of water suffices, and the surplus not needed for the old land leaves water for the new, so that it is apparent how we expect to irrigate more than 300,000 with the present construction and supply. In 1889 we irrigated as late as the last of September; in 1890, in March and the last of August. Fifty inches of water will irrigate 80 acres of land, that is 50 inches for 45 days. Now the supply of the river furnishes the greatest abundance during the months of April and June, and by May the irrigation of any moment is complete. Then the alfalfa needs little or no water during the irrigating season, as the best authorities here agree that abundant winter irrigation is the best method. There are a number of alfalfa fields. Now, I believe that the land north of Phœnix will simply be watered once, and that during winter, allowing seepage to do the rest. Ten years ago the land would have been entirely barren in 60 days without irrigation, and I believe now with one winter irrigation it would produce as many pounds of valuable food as other tracts at present do with summer irrigation.

Did you have any difficulty in June, 1890, as to distribution of your water supply?

Mr. LOGAN. Our water supply during 1890 was in the hands of a water commissioner, and I think there was no loss of crops. There could have been no dispute during 1890 over this matter in this county, which embraces the great majority of the land under corporation irrigation, because the companies had to obey the irrigation commissioner, who divided the water. The cost of water is put at $5.75 per acre, and I should think that that was a fair statement.

What steps are being taken to increase the water supply of Maricopa County by storage?

Mr. LOGAN. Practically none. There is no effort being made at storage. It is a matter of grave doubt if the reservoir system here is a practical thing.

Mr. Logan continued his interesting testimony, which is presented in a condensed form as follows:

There is no appreciable difference in the value of cultivated and uncultivated land under the various ditches except there be some valuable improvements in the way of fencing, etc. The value of land not under ditches amounts to nothing at all. There is no cultivation at all except by irrigation.

The general value of land may be estimated at $25 per acre, with water. It is generally considered that land which is tilled, cleared, prepared, ditched, and planted is worth $45 per acre. It is supposed that $25 is bed rock, divided in this way: That $10 is the price of the ditch per acre, $10 the price of the improvement, clearing, etc., and $5 the profit to the investor. Our water system is in good condition, the progress of the country is receiving very fair assistance at the present time, and in the very near future we will make very considerable growth. I presume that of the 5,000 acres in fruit 1,500 or 2,000 acres were planted during 1890. We feel now that railroad communication to the north is possible, if not assured, and we shall have before the end of 1892 10,000 acres in fruit, and the traffic managers assure us that ample transportation will be furnished. There are 700 acres in oranges now. This country will raise peaches, pears, figs, oranges, olives, and almonds. A large majority of our grape acreage is in raisin grapes, and we have reason to believe that this climate will produce superior products in both grapes and raisins. There is no difference in the soil or insects, and a very little alkali is seen along the river bottoms. The water is good for agricultural purposes. It carries an unequaled chemical fertilizer. As to the filling of the land by irrigation and the increase thereby: I came to Phœnix eight years ago. The alfalfa grower told me then that you had to irrigate but once or twice, and seldom three times, per season. Those who irrigate once do it in the winter. We have a good many wells for domestic use in the valley. The experience of the well-diggers is that they find water at from 17 to 25 feet from the surface. It does not all seem to be on the same level. There is apparently an inexhaustible supply at points near the surface. Then at other points they have to go deeper; for instance, at the city waterworks the well is 45 feet deep. As you get back towards the foothills the depth increases, and at points you have to go as deep as 35 feet. That difference in the depths of wells is not due entirely to the altitude of surface. For instance, it is a little deeper to water on Cave Creek than on New River. I think in Cave Creek it runs from 70 to 140 feet, if it is under the canals. The depth in the neighborhood of Phœnix is from 12 to 20 feet. On the other side of the river the depth at Tempe is 5 or 6 feet, and it runs down to 50 feet. The supply of water for domestic and farm purposes is inexhaustible. The use of natural wells for garden or orchard irrigation is limited.

Mr. T. E. Farrish (ex-Commissioner of Immigration for the Territory), made a statement in relation to statistics forwarded to Washington by himself and his son, formerly employed as an assistant hydrographer in the United States Geological Survey. Among these were the amount of land under cultivation in Arizona. It was given by counties and districts. By request Mr. Farrish forwarded a table of persons owning ditches, with the acreage under them, also acres cultivated.

"In that statement I aggregated," Mr. Farrish said, "over 400,000 acres. By an official report I am referring to, the total acreage cultivated is given at 65,821 acres. In a report made in 1889, to the Senate Special Committee on Irrigation, I estimated the amount cultivated in Maricopa County alone, at three times the figures published officially for 1890. As covered by our present canals in this county, there are, according to my estimate, 267,000 acres. My son, Mr. William A. Farrish, was asked for a census report on the county lands irrigated during the fiscal year 1889–'90. His report was 165,000 acres. The total as officially published for Maricopa County is but 35,212 acres. I also notice clear discrepancies in other counties, in all of which I gave the estimate for each of the ditches. In Apache, I estimated 67,000 acres; in Cochise, 23,000; in Graham County I think it was over 13,000; in Pima, 6,000; and in Pinal, 5,000 acres. In Yavapai I do not remember the exact figures, but now estimate the area at 10,000 acres. In my estimate of the reclaimable land and the possibilities of irrigation I held that there could be reclaimed in this county alone about 3,000,000 acres. This, of course, was considering all possibilities of future storage.

"I think my estimate of cultivation by means of water in sight was 1,500,000 acres, with a proper administration of the present supply, and with a successful storage system there could be reclaimed 10,000,000 acres in the whole Territory. In my report for the United States Senate Committee on Irrigation I put the acreage under ditch at 556,560 acres; land requiring no water entered and occupied at 100,000. The number of acres of irrigated land cultivated in 1889 I put at 256,900 acres."

Hon. N. O. Murphy, acting governor of Arizona, submitted the following statement in writing: "There are under the canal system of the Salt River Valley 300,000 acres, and the canals now constructing will cover 50,000 acres more. There are in the Salt River Valley susceptible of irrigation by the extension of the canals from 150,000 to 200,000 more acres. In the Aqua Fria bottoms there are 20,000 more acres, with a possible 30,000, that may be reclaimed by the extension of the canals. In the New River lands, lying northwest of Phœnix, some 30,000 acres will come under cultivation from the proposed reservoir system now contemplated, making an acreage near Phœnix of 600,000 acres.

"There were planted during April, 1890, the following crops:

	Acres.
Barley, including "volunteer"	45,000
Wheat	10,000
Alfalfa	45,000
Orchards and vineyards planted in 1890 and prior	3,000
Orchards and vineyards planted in 1891	2,000
Oranges, including plantation of 1891	700
Sorghum sugar cane, "volunteer" hay, etc	15,000
	120,700

"The yield of crops per acre with good cultivation is—

Barley	pounds	2,250
Wheat	do	1,600 to 1,900
Alfalfa	crops per year	5

"Orchards and vineyards are young and products can hardly be stated. The total yield of barley was, in April, 1890, 65,000,000 pounds; of wheat 15,000,000 pounds.

"A large proportion of this is in 'volunteer,' which must always be considered."

The Chamber of Commerce sent this office the following statement:

PHŒNIX, ARIZ., *November* 19, 1891.

DEAR SIR: Your favor to the Phœnix Chamber of Commerce, dated November 9, is before me with the request that I give the data asked for:

Grain, 58,500,000 pounds	$731,250.00
Alfalfa hay, 263,000,000 pounds	526,000.00
Grain hay, 5,000,000 pounds	25,000.00
Alfalfa pasture, rented for fattening range cattle brought in from the mountains, 25,000 head, at $3 a head	75,000.00
Dried fruit, 1,000,000 pounds	50,000.00
Promiscuous products, such as sorghum, sugar cane, and small fruits	20,000.00
	1,427,250.00

Respectfully yours,

H. H. LOGAN,
Member Chamber of Commerce.
L. J. WOOD,
Secretary.

RICHARD J. HINTON,
Special Agent U. S. Department of Agriculture, Washington, D. C.

Mr. F. D. Trott, Phœnix, stated that four years ago he was in the employ of the Arizona Canal, and there was then more than 40,000 acres under cultivation in the Salt River Valley system of irrigation, which includes the Arizona and Consolidated canals, and that amount has at least doubled. I am sure it is much more than that. There is no quarrel between the corporations and the people. The great majority of the land in Arizona is under the community ditch system, and there could be no trouble. All our water is distributed by a commissioner.

The books of the secretary of the Mesa City Canal Company, exhibited to the agent, show that 223 persons hold shares in that ditch. The total number of shares is 400. Some of the shareholders sublet their water rights, and there are upwards of 300 irrigators under this ditch alone, and a little over 8,000 acres are irrigated.

Herbert M. Wilson, C. E., member of the American Society of Civil Engineers and geographer in the U. S. Geological Survey, stated in a paper read before the society in August, 1891, that the Salt River has flood waters in sight each and every year of from 10,000 to 20,000 second-feet; that the largest recorded flood reached 300,000 second-feet; while the lowest summer flood is placed at 500 second-feet. The Arizona Canal commands 77,000 acres of irrigable land and the Grand and Consolidated canals, under the same ownership, serves 73,000 acres, making 150,000 acres in all, with more than sufficient water in sight every year for the irrigation of about 1,000,000 acres. This is not a matter of storage except as far as conserving the spring floods are concerned. It is not a matter of going into the mountains at high altitudes and storing the possible storm waters there, but of open flowing water, coming annually, and only requiring competent engineering skill and capital to enable it all to be conserved for use in the valley. Mr. Wilson's statement has this importance, that he is, at present, the Geological Survey's expert for all hydraulic engineering possibilities in the arid region.

The admirable works constructed and operated on the north side of the Salt River by the Arizona Company are justly commended in Mr. Wilson's paper. The personal examination made in the summer of 1891, and the personal knowledge of the special agent in charge, dating back to 1877, justifies the statement that the Salt River Valley in Arizona is exceedingly well equipped with irrigation works, well administered, has an abundance of water in sight, and is possessed of a semi tropical climate and a fertile soil that makes all plant life luxuriant in growth and production.

UNDERGROUND WATERS IN ARIZONA.

Messrs. H. H. Logan and Lincoln Fowler, of Phœnix, two of the most observant and intelligent irrigation organizers in Arizona, in response to questions from the irrigation inquiry, present the following statements.

Mr. Logan writes:

I have studied central and southern Arizona with a great deal of interest for the past eight years, have crossed over almost all of its valleys and mountain ranges, and have examined the districts where the formation changed and contact veins appeared, with a growing interest during all this time. My observation has led me to believe that a large part of central, southern, and western Arizona is in an artesian belt, taking in the district lying east of the Colorado and north of the Gila and Salt rivers.

Arizona, draining as she does all the country lying between the Rio Grande and Colorado rivers—a country enormous in extent (some 600 miles square), much of it being high elevations covered with large bodies of snow during the winter months—and all of these waters passing out of this belt through the channels of the Salt and Gila rivers, shows a surface drainage during the summer months of much less than 1 per cent. I find in many localities under both rivers, within a radius of 100 miles, springs cropping out from the mountains, flowing in many instances several inches of water that are beyond any question artesian in their nature. Take the Caliente Hot Springs on the Gila River, in the western part of Maricopa County, that flow some 500 or 600 inches of water, then follow the water granite formation through any of these mountains at high elevations, and frequently on the tops of ridges where the drainage would be almost entirely away from the surface, are springs of water, usually found in the chimney of water granite. Take the mountains lying south of the Gila: about 12 miles southwest from Phœnix, there are springs along the sides of the mountains that flow small trickling streams of water that is forced up through the seams in the rock. You take it to the north of Phœnix: in the McDowell Mountains, at an elevation of fully 3,000 feet, very close to the summit of the mountains, is an artesian spring that flows some 3 inches of water; it follows up the slate formation that crosses northwest and southeast.

At old Camp McDowell, Mr. Andrews, while there running the pumping station, drilled with 1½-inch water pipe some 400 feet in the bed of the Verde River; he struck there some three flows of water that raised some 35 feet above the surface of the ground. The well was not tubed, and had passed through very considerable stratas of quicksand, the main deposit being coarse gravel; no rock was struck. The well uncased, simply plugged at the top, raises water some 25 feet, and has flowed a small stream for the last year. The water is very soft and exceedingly pure. This well at McDowell is some 10 miles northeast of the spring in the McDowell Mountains and to the north of this slate formation spoken of as crossing at the spring.

Between Phœnix and the Verde River, at different points, are springs showing the same character of water. Such indications by the way of seepage, etc., are shown on both sides of the Matazal Mountains at frequent points, but almost universally in water granite.

Some 16 miles west of north of Phœnix is what is known as the Beechum well, which, I think, is about 145 feet to water. Lying east of Beechum well, some mile and a half or 2 miles distant, is a sandstone mountain. No moisture was reached in the well until the rock, the shelf of this mountain, was reached. When the rock was uncovered, water running, apparently under pressure, at least that made a noise sufficiently to greatly intimidate the workmen, was heard. The well was not curbed, but was built through a general cemented gravel down to within 5 or 6 feet of the bottom or this rock; it was there curbed and some 3 feet of rock blasted out, when the water rose immediately to the top of the curbing, and has been perpetual for some years, and came in in such quantities that the tools that were used in the last work are still in the bottom of the well.

Take the valley of Cave Creek its entire length, and it is unquestionably in an artesian belt, and probably the same may be said of a large part of New River. The indications point strongly to there being an underpressure, draining, as Cave Creek does, quite a large belt of mountainous country, none of which reaches surface or any possible bed-rock surface drainage for the last 20 miles of its length.

Mr. Lincoln Fowler accompanied the following paper with a Land Office map, on which by numbers is indicated the section he is considering. As it is not desirable to reproduce this, the effort is made to indicate the localities in letterpress. Mr. Fowler says:

Arizona is overdrained in the region of the high plateaus of the north, by the cañon of the Colorado and its lesser tributaries, to such extent that the probability of water being secured from the underflow by artesian wells is very slight. This condition will apply approximately to the northern third of the Territory. The eastern boundary of Arizona follows substantially the watershed of the continent, and at a point slightly north of the center, extending east and west, is the culmination of the plateaus, which are perhaps in reality the southern end of the Sierra Nevada range of California and Nevada. From this crest across Central Arizona, extending southward, are many lesser mountains and hills, and at the southeastern corner of the Territory these ranges extend continuously into Mexico, cut across by the Gila River, in a deep and tortuous cañon, draining from that part the San Simon, Sulphur Spring, and San Pedro valleys.

(The region suggested in the foregoing paragraph by Mr. Fowler, follows on the plateau lines down to and east of the Mogollon range and thence by way of the Chiricahuas and other detached ranges southward into Mexico. Another segment which begins at the southern base of the Francisco Mountain, where the Atlantic and Pacific Railroad crosses the plateau, moves southeasterly along the slope of the Mogollon range into the broad valley or plains south of the Gila River. These valleys and plains are well known as endowed with a large phreatic water supply, lying very near the surface.)

In the San Simon Valley [continues Mr. Fowler] there would seem to be excellent opportunities for artesian wells, as numerous rivulets disappear after leaving the foothills, and many wells are had by cattlemen at depths of from 40 to 80 feet.

The Sulphur Spring Valley takes its name from a group of sulphur springs near the center, and a number of other springs are found at the edge of the plain. There have been a number of artesian borings made, and in several a very good flow of water obtained. A curious circumstance occurred at the time of the severe earthquake of the 3d of May, 1887, when numerous fissures were opened in this valley, from many of which issued running water, thereby proving the existence of underground channels. Another sight then took place, of the cowboys and ranchmen of that section locating, within an hour, on the principal springs for stock ranges, thus availing themselves of the beneficence of Providence at once, regardless of continued tremors. This point was about 100 miles from the center of seismic disturbance, which was in Northern Sonora. Some of the earthquake-developed springs have continued permanently, but most of the smaller ones dried up after a short flow. This valley, some 30 miles wide and 60 miles long, is drained southward into Mexico by the San Pedro River, and thereafter this river turns again into Arizona and runs northward through a narrow valley or cañon to the Gila. The valley of the San Pedro is so slight in width that the river water will probably more than suffice for its development; and it seems unlikely that any expenditure will be made to test the question of artesian flow.

(The central development of springs mentioned by Mr. Fowler is found on the southeast portion of the Caluiro range, at Tres Alamos, and north of Benson on the Southern Pacific Railroad.)

Extending from the Sonora line northward, at about the center of Southern Arizona, is the valley of the Santa Cruz. This stream, rising in high mountains, drains a large area of country with but a trifling surface flow, and for a considerable disance between Tucson and the Gila River, into which it empties, has no surface channel, and in time of flood forms a wide flow through the brush of the plains. There are, however, several places along the underground channel of 75 miles or more, where stockmen and the Southern Pacific Railroad have sunk wells and found uniformly a very good supply of water at moderate depths. So far as the writer knows, no one has ever sunk a cased well on this channel for testing the strength of the flow or if sufficient pressure might be had to cause an actual flow to the surface as artesian water. This would surely be a promising field, for a valley of fertile land, as over one hundred miles in length, awaits the successful issue of such a test.

(The Santa Cruz Valley contains, within from Nogales, on the Sonora line, to Maricopa, near the Gila River, several important settlements and the city of Tucson, the largest in the Territory. There are now over 5,000 acres under cultivation in the drainage basin of the Santa Cruz, while ditches have been constructed to serve about 30,000 acres. There is no reason to doubt that the subterranean flow of the river may be reached and utilized. The number of dug and driven wells already in operation at thriving railroad points, such as Tucson and Casa Grande, are in evidence. Projects are under way looking to retaining the stream flow above by means of bed-road dams, etc., but even then a large supply will find a subterranean course.)

Mr. Fowler calls attention to phreatic water supplies found on the Papagoria, an extensive volcanic plain or table-land with a few isolated ranges lying west of the Santa Cruz, south of the Gila, and east of the Lower Colorado. He says:

> There are in the Quizota Valley and at other points in the vicinity of the Ajo copper mines along the southern border, promising localities of fertile land, needing only water for reclamation, which in the absence of surface flow, except that of torrents, much must be supplied by artesian flow, if at all.
>
> Along the Gila Valley the waters seem to be nearly or quite brought to the surface at many points by the bed rock, which from its character and stratification would hardly admit of the belief that any useful purpose would be served by borings, except on the last 100 miles of its course.
>
> In Southwestern Arizona, but generally to the north of the Gila, the drainage of a large district east of the Colorado from Cullens Valley passes through a defile in the Harqua Hala Mountains and at a lower point through a range of hills is again within a few feet of the surface with indications of a large flow. Between these two points and south of the Harqua Hala Mountains is a very fine tract of excellent land 25 by 50 miles in extent at least, and there would seem to be every reason to expect that artesian flows of water might be had at different points. This would be a great prize to be gained, more than 500,000 acres of land suited to the orange and vine only lacking water. From this valley to the Gila River there is a fine extent of country equal in every way, except size, to the last and overlying the same channel of underflow.
>
> The valley of the Hassayampa, for more than 40 miles, is an admirable field for artesian development, presenting an area of over 200,000 acres, and wholly untried for flowing water, although the configuration of the valley is such that the large underflow which must pass should certainly produce successful results.
>
> Again, in the valley of the Agua Fria, there are evidences of very similar conditions to those of the Hassayampa, with, perhaps, a larger drainage. The valley is of somewhat less extent. No tests have been made, except that near the lower end of the valley, surface wells 40 to 60 feet deep will show a rise of several feet when the covering of the water strata is broken, though no artesian borings have been made.

(The whole area referred to in the foregoing paragraph lies south and west of the famous Salt River Valley at Phœnix to the Colorado River and south to the Gila. It embraces a number of small but fertile drainage basins, small valleys in which some farming is in progress. It is a section of the Territory in which considerable mining is being done, and wherein larger developments are certain to come whenever accessibility to supplies can be assured. The utilization of phreatic waters will materially advance these conditions.)

Says Mr. Fowler:

> In the Rio Verde Valley a small bore was made at Fort McDowell, about 8 miles from the junction with the Salt River, into which the Rio Verde empties. At a depth

Phreatic Waters in Arizona. Wells at Casa Grande.

of 276 feet a flow was found, but on account of the small size of the pipe, 1½ inches, only a little water was obtained. This might be increased by using larger bores, and the valley is equally promising for a considerable distance. At a place near Pinal two or three small flows were struck at depths of about 100 feet, and in the valley of 250,000 acres lying below, between the Salt and Gila rivers, no one has ever tried for artesian water.

In Arizona between five and six millions of arable land await the husbandman, who is ready when the fertilizing touch of water is to be had; and almost the whole of that vast area is well adapted to oranges, figs, or the choicest vines.

With more than a thousand acres of orange orchards scattered in Salt River Valley about Phœnix, and many times that of raisin and wine vineyards and the finest fig orchards in the West, we may hope for great results.

The artesian wells in the Verde and Sulphur Spring valleys and the Pinal region certainly give assurance that we can expect flowing wells to be had at many points on the known underflow channels yet undeveloped by borings.

The most important of the subterranean stream flows (though not the only one in the Territory) is that of the Santa Cruz River. It is so peculiar and significant in character as to warrant a description of its features. It rises, then, in the southeasterly corner of Pima County, Ariz., about 20 miles north of the Sonora State line, Mexico, and courses nearly due south, crossing the Arizona line into Sonora some 18 miles, makes an elbow and reënters Arizona not far from Nogales on the Mexican frontier. The course, then, of the river is northwest to Calabasas and Tubac, and thence nearly due north to Tucson; from that point its course is northwesterly to a junction with the Gila River near the Maricopa Wells. The river is in some respects a phenomenal water course, being at times a stream from a few feet to a quarter of a mile wide with a depth of but a few feet to sufficient to float the largest Mississippi River steamboat.

The contour of the watershed of the main stream and its branches is very irregular, and the drainage area may be roughly estimated at 7,500 square miles. From its source to Tubac the stream is quite large and shows a dry season surface flow varying from 2 to 10,000 inches. From Tubac to San Xavier del Bac (Papago Reservation) most of the water course is subterraneous, and thence to Point of Mountain, 18 miles below Tucson, the flow alternately appears and disappears. From Point of Mountain to the junction with the Gila River it practically disappears and is an underground river, its course in many places and for many miles being traced by a belt growth of mesquite trees from 500 to 2,000 feet wide. The hydrographic physical features of the valley are little understood. Underlying the valley is an almost continuous body of coarse gravel, through which water percolates to an unknown depth. It has been tested at Tucson to a depth of 52 feet, all in this water-bearing material, and an estimate approximately made covered a width of from 1,000 to 4,000 feet, and to the depth tested, allowing only one-tenth of the area for water, percolation would bring some 370,000 irrigating inches every twenty-four hours. Add to this the enormous quantity that could be stored in great catchment reservoirs from two rainy seasons—winter and summer—and the possibilities can be better seen of the importance of this region. Another extensive drainage supply could be taken from the Pantano cienego region, known as the Rietta Creek, 22 miles easterly of Tucson, a branch falling into the Santa Cruz, about 6 miles below Tucson. To the casual observer passing through this country upon the railroad it has the appearance of being a worthless, more than semi-desert, region. By proper treatment and intelligent engineering skill it would soon compare in crops and food products with other accepted sections of great richness and importance in the variety and abundance of its products.

As to other evidence, Capt. W. P. Williams says that with a Worthington pump he gets 200 inches of water within 1 mile of Maricopa. Capt. Henry Arey, of Maricopa Station, said:

> In order to get parties interested in land around Maricopa Station, I had a well sunk at a cost up to date of $5,000. The plant is a Worthington pump and reservoir with a capacity of 2,000,000 gallons. The well is sunk in what is supposed to be the lost bed of the Santa Cruz. It is 58 feet to bed rock, and there are 13 feet of water in the well. Two acres were put in late last year, but the pump was not ready until March—too late for this crop. My opinion is that tha Santa Cruz flows along the bed rock; and that while $2.50 per inch is charged for water from the ditch I can pump it from the river for $1.25. By drifting out from the well chamber into the bed of the Santa Cruz I can at least double my supply and perhaps do better. The well can not be cut off.

The Southern Pacific is digging another well in the neighborhood and gets water at a depth of 45 to 50 feet. They also think the water comes from the Santa Cruz. The strata gone through are red loam, sand, then a cement that had to be blasted through for 16 to 17 feet, then loose gravel in the bed of the Santa Cruz for a distance of 30 feet, and then down to bed rock. The water chamber of the well is 10 by 10 feet, and the river flows right through it from northeast to southwest.

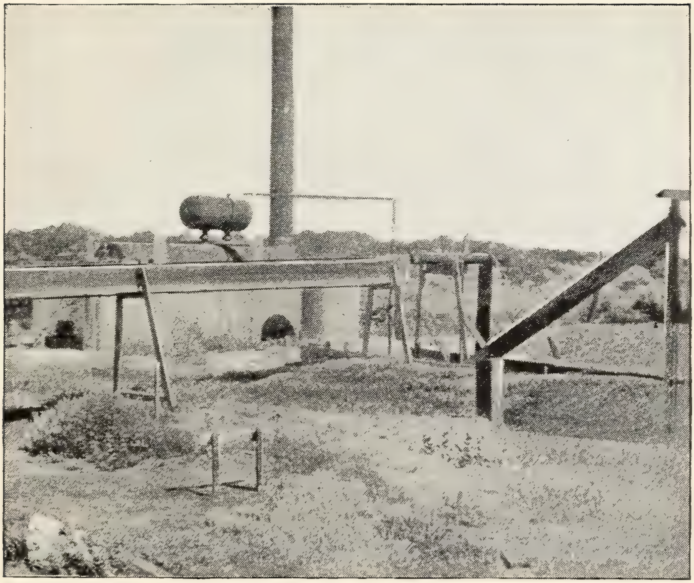
An hydrographic study of the Santa Cruz Valley, especially that portion from the Sonora line to Point of Mountains, a distance of some 90 miles, leads to the conclusion that by developing and husbanding the underflow of this great drainage basin the greater part of the arable area within these boundaries could be irrigated. The Valley from Nogales to Tucson is a rich soft loam, capable of producing a great variety of agricultural products and fruit. At San Xavier a rock barrier has been thrown across it by volcanic action, producing a narrowed gorge, where a catchment dam could be built to bed rock and impound an immense body of water. This place is known as the Punta de Agua (place of water). Thousands of acres of fine land could be successfully irrigated from this great natural reservoir. The site of this dam is on the Papago Indian Reservation, and the contour overflow lines would fall partly into the reservation and partly outside. This importnt a location can not be used until action is taken to free the site from connection with the reservation. The Indians make very little use of the water, and have allowed the fine farms below it on the reservation to lapse into a wild growth of weeds and disuse. Turned to civilized uses it would be of vast benefit to Tucson and furnish water to a great number of settlers.

ANSWERS FROM CORRESPONDENTS.

The following summaries are made from replies received to circulars sent by this office:

APACHE COUNTY.

Snowflake (post-office)—Jesse N. Smith (October 5, 1891):
Water supply, Silver Creek. Large supply winter months. Small supply in growing season.
Irrigation Works—Four main ditches, aggregating 15 miles in length, about 7 feet on top, 5 feet on bottom, one main headgate for each ditch. "Two reservoirs, area three-quarters of a mile and 2 miles."
Cost of ditches per mile, about $500.
Cost of reservoirs, $1,500 and $2,500 respectively.
Average cost per acre of irrigation works, ditches, etc., about $12.
Average cost per acre for preparing land for cultivation by irrigation, about $10.
Average cost per acre for annual maintenance and repairs, about $2.
Staple products under irrigation, and average value per acre, wheat, $24; corn, $20; oats, $20; alfalfa $30; potatoes $40.
Area under ditch, 3,000 acres.
Area under cultivation, 2,300 acres.



Raising Water from a Lost River. Well with Worthington Pump in Bed of underground Rio Santa Cruz. Near Maricopa, Arizona.

COCHISE COUNTY.

[Data compiled from or report made by the board of county supervisors to a United States Senate Special Committee on Irrigation, in 1889. Area of county, 6,972 square miles. Three principal valleys are mentioned, viz, San Simon, Sulphur Spring, and San Pedro.]

San Simon Valley (in eastern portion of county)—watered by San Simon Creek, which has a drainage area of 144 square miles. "Soil of valley in many places being sandy, this stream runs underground, and comes to the surface at points only where the clay bed or bed rock comes near the surface, at which points an abundance of water is shown; greater part of valley could be irrigated and made very productive could these waters be utilized;" but little irrigation in valley; only about 2 miles of ditches; not exceeding 300 acres in cultivation; susceptible of cultivation, 6,000 acres. (The first artesian well obtained in Arizona was in this valley, in 1882, of which there are now quite a number.)

Sulphur Spring Valley (through central portion of county) lies between several ranges of mountains on its east and west sides; drains an area 30 miles wide and 90 miles long. "The waters of this valley flow southerly into Mexico, and form the headwaters of the Sonora River. Waters of this valley also flow underground, forming an abundant supply but a few feet from the surface. Not over 4 miles of ditches in valley; about 2,000 acres under cultivation in valley and foothills adjacent; susceptible of cultivation by irrigation, 200,000 acres.

San Pedro Valley (in western portion of county) lies between ranges of mountains, and is watered by San Pedro River, which rises in Mexico and flows northerly through this county and empties into Gila River in Pima County; river has a watershed in this county of 25 miles in width by 80 miles in length, and a total watershed (including that in Mexico) of 2,700 square miles, the waters from all of which pass through this county. This valley also has "a large under ground current," rising to the surface at intervals, as in the other valleys; valley quite thickly settled; about 40 miles of ditches; all main ditches supplied from main stream of river, by means of brush and earth dams usually (sometimes by dams made by sacks of sand) diverting water into ditches. Dams washed away by every flood. Lands under cultivation, 6,000 acres; susceptible of cultivation by irrigation, 50,000 acres. (The lower part of this valley presents a promising field for the development of an artesian supply for irrigation.)

There are many large springs in the county which might be utilized to irrigate orchards and vineyards in the foothills and higher table lands. Some of them are now used by means of ditches to irrigate vegetable gardens and orchards, and some by means of pipes are utilized for the watering of stock. Certain reservoir sites are designated by the board and their construction recommended. (Great progress has been made since the date of this report throughout the county.)

GRAHAM COUNTY.

Safford (post-office), E. D. Tuttle (September 27, 1891):

Water supply: Gila River, stream large in spring but small in July and August; large underground stream, the river sinking and rising to surface at intervals of a mile or thereabouts where dams are made and canals taken out.

Works: Between the Narrows (8 miles east of Solomonville) and Fort Thomas (38 miles west) there are 20 canals, averaging 8 feet wide on bottom, 10 to 12 feet on top, "with average depth after reaching surface of 3 feet in the soil;" length from 2 to 8 miles with average grade of 4 feet per mile. Each canal has head and waste gate, with simple distributing gates for each farm. Canals all dug and maintained by owners of land irrigated. The laterals are easily and cheaply made. Lands have a generally even and gradual slope. The dams are only temporary.

Area under ditch, 50,000 acres, approximately.

Area under cultivation, 15,000 acres.

Cost per mile of ditches, $500, average; cost of water to user per acre, $2.50; no rental of water.

Average cost per acre for preparing land for cultivation under irrigation: Bottom lands along Gila River, from 1 to 2 miles in width, and auxiliary lateral valleys are covered with mesquite and sagebrush; cost of clearing this about $5.

Cost of annual maintenance and repairs: About 30 per cent of first cost of canal. This cost is largely out of proportion to the first cost of the canals, etc., on account of the floods that tear out the headworks, carry away the dams, and fill canals with silt or mud.

Staple products under irrigation: Alfalfa, corn, wheat, barley, oats, sorghum, potatoes, beans, etc. (alfalfa is the principal forage crop, giving five cuttings per year, and giving pasturage all winter).
Average value of product per acre: Alfalfa, $20 to $25, gross; small grain and corn, about $15.

MARICOPA COUNTY.

Phœnix (post-office), H. H. Logan (September, 1891):
Salt River Valley (600,000 acres): Water supply, Salt River.
Works: Ten main canals (about 300 miles); from 15 feet to 36 feet on bottom; carrying from 3 to 7½ feet of water; laterals, over 5,000 miles; no reservoirs; only 1 dam on Salt River which is 945 feet long, raising the water 8 feet; 10 headgates.
Area under these 10 canals, 300,000 acres; under cultivation, 145,000 acres.
Average cost per acre in the past for irrigation works, probably $5.50 to $6.
Average cost per acre in the past for annual maintenance and repairs, 60 to 75 cents.
Average cost per acre in the past for preparing land for cultivation under irrigation: For clearing, bordering, and ditching, about $2; for putting it into grass, about $5 additional.
Cost of water supply to user per acre, average $10; annual rental, $1.
Staple products under irrigation: Wheat, barley, alfalfa, sorghum, sugar cane, apricot, peach, prune, pear, fig, grape, nectarine, orange, and lemon; all staple vegetables grown during the entire year.
Average yield per acre: Wheat, 1,700 to 1,900 pounds; barley, 2,200 to 2,500 pounds; alfalfa, 8 tons; sorghum, 30 tons. No reliable data of fruit yield, except the raisin grape, 7 to 10 tons per acre on 3-year-old vines.

Phœnix (post-office), Lincoln Fowler (September, 1891):
Grand, Maricopa, and Salt River Valley canals: Water supply, Salt River; capacity, from 350 cubic feet per second, upward.
Works: Grand Canal, 24 by 4 feet, 35 miles long; Maricopa and Salt River Valley canals, joint head, 24 by 4 feet; ditches 50 miles long. Headgates: Grand Canal, 100; Maricopa and Salt River Valley canals, 75.
Area under ditch, 50,000 acres; under cultivation, 30,000 acres.
Cost per mile of canals, etc., $500 to $10,000.
Average cost per acre for irrigation works: Canals, ditches, etc., $10.
Average cost per acre for preparing land for cultivation under irrigation, $2.50.
Average cost per acre for annual maintenance and repairs, $1.25.
Cost of water supply to user per acre, $10.
Products under irrigation: Alfalfa, wheat, barley, oranges, grapes, peaches, and other fruit.
Average value of product per acre, from $15 to $250 (wheat and barley, $20; alfalfa, $30).

Tempe (post-office), E. G. Frankenberg (October 17, 1891):
Tempe Canal system: Water supply, Salt river; supply insufficient in summer.
Irrigation works: Water diverted by two brush and rock dams, tightened with sand and gravel, by one into an old channel of river, by other into canal proper. Main canal 1½ miles long, 28 feet on bottom, 40 feet on top; two branches 5 and 8 miles long; also southern extension 23 miles. (Laterals not included in above.) One main head gate; also one at head of each branch; two waste gates and ditches returning water to river.
Area under ditch, 25,000; under cultivation, 22,000 acres.
Cost per mile of works, main canal, $25,000; first branch, $1,000; second branch, $800; southern extension, first section, $1,375; second section, $750; third section, $500; fourth section, $350.
Average cost per acre for ditches, etc: For main canal and branches, $2.75 to $3; for laterals and distributing ditches, $1 to $3.
Average cost per acre for preparing land for cultivation under irrigation: For grain raising, from $2.50 to $3; for alfalfa grazing land, $3 to $5; for fruit culture, $5 to $15.
Average cost per acre for annual maintenance and repairs: Main canal and branches about 50 cents; laterals, etc., 25 to 75 cents.
Chief products under irrigation at present, wheat, barley and alfalfa. In the near future fruit culture will be the principal occupation of the land owner; as the climate and soil of this valley are especially adapted to the growing of oranges raisins, peaches, apricots, figs, nectarines, dates, plums, pears, etc.
Average yield of product per acre: Wheat, 1,500 to 2,000 pounds; barley, 2,000 to 2,500 pounds; alfalfa, 3 to 8 tons can be cut monthly.

[Mr. Frankenberg states that he gathered 9 tons of peaches per acre; 500 pounds of raisins per acre from 2-year-old vines; 6,400 pounds of almonds per acre; 8 tons of wine grapes per acre, from 8-year-old vines.]

Mesa City (post-office), C. I. Robson (October, 1891):

Water supply, Salt River; when river is full 8,000 inches are used; present supply, 2,000 inches (October, 1891).

Works: 10 miles main canal; 23 feet on bottom; bank slope, one to one; no reservoir; dam one-half mile long; average height, 5 feet; one main head gate; one waste gate or overflow.

Area under ditch, 8,000 acres; under cultivation, 4,000 acres.

Cost of main canal per mile, $5,600.

Average cost per acre per canal, etc., $7.

Average cost per acre for annual maintenance and repairs, $1.50.

Average cost per acre for preparing land for cultivation by irrigation, $2.50 (average).

No rental of water; water users are owners of works, etc.

Staple product under irrigation, grain, hay (alfalfa), and fruit.

Average yield of product per acre: Grain, 1,500 pounds; alfalfa, 5 tons; value of fruit yield per acre, $50.

MOHAVE COUNTY.

C. M. Funston (Kingman post-office), and W. G. Blakeley (Mineral Park post-office).

About 80 miles south of Kingman there are irrigation ditches (probably 20 miles), none exceeding a mile in length; mostly crude and small; owned by farmers; water supply, Sandy River and spring.

In vicinity of Mineral Park "no land is cultivated except little garden spots, watered by small springs or wells on premises; mining chief industry."

Area under ditch in county, about 1,000 acres.

Area under cultivation in county, about 800 acres.

"Very little produce raised, but cereals, fruits, and vegetables could be successfully grown with proper irrigation facilities."

PIMA COUNTY.

W. A. Hartt (18 miles south of Tucson):

Reports water from well located in Santa Cruz Valley; well 4 by 4 feet, raised 60 feet by compound pumping engines; continual capacity, 2,500 gallons per minute.

Works: 3 miles main ditch, 4 feet on bottom, 12 feet on top, 3 feet deep; about 15 miles laterals. One reservoir (storage), capacity 200,000,000 gallons; supplied by surface or flood waters. One distributing reservoir, 7,000,000 gallons; other works, one pulsometer pump; capacity, 1,000 gallons.

Area under ditch, 1,920.

Area under cultivation, 600 acres.

PINAL COUNTY.

Kenilworth (post-office), Thomas W. Graham (October 14, 1881):

Water supply: Gila River, through Florence Canal. Plenty of water in river, but poorly constructed canal.

Works: Canal 40 miles long, 18 feet wide on bottom, all dirt work. One reservoir, area 1,800 acres; will hold 4 feet of water. Head gate destroyed by flood last February; not rebuilt by company.

Area under ditch by this system (Florence Canal), 100,000 acres.

Area under cultivation by this system (Florence Canal), 10,000 acres.

Cost of water to user per acre, $8 (water right, this system).

Annual rental cost $1.25 per acre.

Average cost per acre for preparing land for cultivation under irrigation $5 to $10 (high or mesa land costs less than river-bottom lands on account of less growth to be removed or cleared).

Chief products under irrigation: Alfalfa, barley, wheat, apricots, grapes, and figs.

Average yield per acre: Alfalfa, 4 tons; wheat and barley, 1,500 pounds.

[Mr. G. states that he is unable to estimate the cost of works, ditches, etc., or maintenance and repairs; this can only be obtained from company.]

YUMA COUNTY.

Chrystoval (post-office), O. F. Thornton, president South Gila Canal Company (September 26, 1891):

Water supply, Gila River (near Oatmans Flat, Maricopa County).

Works, 22½ miles of ditch, 12 feet on bottom, 20 feet on top (to be used as lateral after completion of canal); one head gate; no reservoirs.

Area under ditch, 18,000 acres (when main canal is completed there will be 130,000 acres).

Area under cultivation, owing to floods last season, and this being a new country, very little land cultivated.

Cost per mile of canal, $2,000.

Average cost per acre for canals, etc., $5 to $10.

Average cost per acre for preparing land for cultivation under irrigation, $5 to $25.

Average cost per acre for annual maintenance and repairs, not less than 25 cents.

Cost of water supply to user per acre, $1.50.

Products, wheat, barley, Egyptian corn, alfalfa, sorghum, beans, etc.

Estimated value of product per acre, $25.

Mohawk (post-office), George W. Norton (September 25, 1891):

Mohawk Canal water supply, Gila River at Texas Hill; capacity of canal, 10,000 inches.

Works, 33 miles canal, 14 feet on bottom for 8 miles, slope 2 to 1; remaining distance, 10 feet on bottom, slope 2 to 1; one head gate; no other works.

Cost of canal, $150,000.

Area under ditch, 30,000 acres; under cultivation, 10,000 acres.

Average cost per acre for irrigation works, ditches, etc., about $10.

Average cost per acre for preparing land for cultivation under irrigation, about $20.

Average cost per acre for annual maintenance and repairs, about $5.

Cost of water supply to user per acre, $10; annual rental cost, $1.25 to $2.50.

Chief products under irrigation, vineyards, wheat, barley, alfalfa, etc.

[Country too new to estimate average yield or value of product.]

Palomas (post-office), A. E. Martin, president Farmers' Irrigating Canal Company (September 28, 1891):

Water supply, Gila River; 5,340 miner's inches for canal.

Works, 18 miles canal; first 6 miles 10 feet on bottom, 19 feet on top, 3 feet deep; second 6 miles 6 feet on bottom, 15 feet on top, 3 feet deep; last 6 miles 4 feet on bottom, 13 feet on top, 3 feet deep; one head gate; no reservoir or other works.

Area under ditch, 4,800 acres; under cultivation, 590 acres.

Average cost per mile of canal, etc., $1,611.11.

Average cost per acre of canal, etc., $6.04.

Average cost per acre for preparing land for cultivation under irrigation, $1.87.

Average cost per acre for annual maintenance and repairs, $9\frac{6}{10}$ cents.

Products under irrigation, wheat, barley, corn, sorghum, alfalfa, and garden vegetables.

Average yield of product per acre: Wheat, 50 bushels; barley, 55 bushels. Two crops per year are raised. Wheat and barley first. Then corn and sorghum.

Yuma (post-office), F. S. Ingalls (September, 1891):

Water supply, Colorado River.

Works, steam pump, 6,000 gallons per minute; 3 miles of ditch, 14 feet wide on top, 10 feet on bottom; no reservoir or other works.

Area under ditch, 3,000 acres; under cultivation, none at present.

Cost per mile of works, ditch, etc., not to exceed $300.

Average cost per acre of irrigation works, ditches, etc., about $5.

Average cost per acre for annual maintenance and repairs, nominal.

Average cost per acre for preparing land for cultivation under irrigation: Clearing, $2.50; leveling and ditching, $25.

Cost of water supply to user per acre and rental cost, not yet fixed.

Products, no data.

Irrigated Orange Orchard at Los Angeles, California.

CALIFORNIA.

In dealing with the climatic conditions of California, and (so far as related thereto) of Nevada, as connected with irrigation, Lieut. Glassford, Signal Corps, U. S. Army, now in the Weather Service, Department of Agriculture, has presented in the report ordered by Congress, an interesting theory of climatology which has much to recommend it to consideration. Examination testifies to the accuracy of the statement that "two influences dominate the climate of California, radically dissimilar in every particular, combining in ever-varying forces to produce the resultant which is recorded by observers of the weather. One is the sea tending always to charge the air with moisture, the other is the mountain mass tending always to discharge the moisture from the air. The combination of these two activities in varying proportions is responsible for the variation in the amount of precipitation."

It is necessary of course to consider both of these influences. The topographical factor comes first. The chief mountain formation of the two States includes "the maximum extension in latitude of the Cordilleran system." The "characteristic orographic feature" of the region is the Sierra Nevada, and it is also "the predominant" climatic instrument, both for California, to which it gives the rain, and for "Nevada, from which it withholds" the same. The Sierra Nevada itself is about 600 miles from north to south. The northern extension of the range, the Cascade Mountains in Oregon and Washington, have a lineal extension of nearly 700 miles. The culminating center of the Sierra Nevada is Mount Whitney, towering 14,898 feet above the sea, in the San Joaquin Valley. The general elevation is carried from that mount northward for over 100 miles at about 11,000 feet. Southward it descends to about 8,000 feet. Lake Tahoe, to the north, is just below the 9,000 feet contour, and beyond that, after the Central Pacific Railroad crosses at about 7,000 feet, the range rises again to Shasta, with a general elevation of about 8,500 feet. Below the San Bernardino Range the Caccopah Range breaks down in the Colorado Desert to an altitude of about 5,000 feet. The western slopes of the Sierra are scored with deep and precipitous cañons, and are marked as they descend into the deep trough-like valleys of the San Joaquin and Sacramento, with a wide area of rugged foothills. The total length of this portion is 400 miles, varying in width from 40 to 70 miles, where the western rim is made of the Coast Range. It is said—

> The eastern limit is fixed with considerable precision of definition at a practically constant distance from the western limit of the Sierras, the expansions are uniformly made by encroachments upon the sea. The system comprises a multitude of subordinate ranges, some large and some small. * * * The general trend of the sub-ranges as of the system at large is with a tendency toward parallelism with the coast.

The parallelism with the greater Sierra Range is complete. The northern and southern extremities of the Coast Range unite or swing in upon the great valley.

And so enter upon the vaster mass and elevation, to the north at Shasta and to the south in Kern County. Geological conditions alone indicate the primary divergencies of the two systems. Below the Tehacapi Range, it is not quite possible to distinguish, except as to the San Bernardino Range, whether the broken formations are to be classified with the Sierra or the Coast Range. Nevada may be described generally as within the Great Basin region. The western section of course lies more directly under such climatic influences as rise from the eastern slopes of the Sierra Nevada. For the purposes of cultivation by irrigation the great interior valley formation of California is the most important. With the certain growth of the district system, insuring as it does security for investment and safety for water control and administration, the Sacramento and San Joaquin valleys are to become more rapidly the acme centers of irrigation industry. Elsewhere in the Golden State, special localities, each perhaps limited in area, but most valuable for special crops and products, will occupy a large share of public interest, but the valley or plain which lies between the Sierra Nevada and the Coast Range, east and west, and the Shasta and Tehacapi cross ranges north and south, will be the dominant agricultural region; as in part for vines and desiduous fruits, it will also be the center of horticultural and viticultural activities.

Between the great mountain walls indicated, this vast troughlike plain has a length of about 450 miles and maintains the average breadth of 40 miles, taking in the lower foothills so far as they are available for agriculture, and thus contain some 18,000 square miles or 11,520,000 acres. The only breach in its mountain wall is at San Francisco, midway of its length, and at the water level this gap is less than a mile wide. The vastness and majesty of the mountain formation is no more significant than its simplicity. The nature and character of the "oceanic factor" in the Pacific coast climatology is equally as well marked by these two massive and cosmical features. The Pacific, which is the largest mass of oceanic waters, is also the least subject to disturbance or perturbations.

Mr. Glassford says:

Its conditions are constant over large areas, its currents both of wind and water are drawn in broad sweeping curves in which extent of space and time of passage serve to override all mere local or temporary modifications. Thus it is enabled to present almost the ideal problem of oceanic circulation and to array upon the climate of California, and in a modified degree upon that of Nevada, a few simple influences which become involved and difficult of study only through the continental disturbances.

That part of the Pacific Ocean which is related to the California coast stretches westward for nearly 100 degrees of longitude, with its farther horizon above the Chinese Sea, and its northern and southern extremities at the Aleutian and Philippine Islands, respectively. No land mass borders on the southern rim of this oceanic plain, while at the north are found the peninsula of Alaska and the Aleutian Islands, yet the meteorological distinction between the North and South Pacific is clearly defined at both borders. For its effect on our climate—

It exists at the thirtieth parallel of north latitude. Below this bounding line is the region of the northeast trade wind and the west drift of the equatorial current and these two serve sufficiently to bound in wind and water the great basin above.

It is a basin within these limits, a rough ellipse having a major axis of 10) degrees of longitude and a minor axis of 25 degrees of latitude. It has its characteristic system of circulation both of atmosphere and sea. The strongly individualized ocean current of the region is the Kuro Siwo. Developed from the cumulative progress of the equatorial drift and directed by the alteration in the plain of the sea bottom and the trend of the Asiatic coast this warm stream moves across the whole northern Pacific. Occurring in a broader sea it shows several important differences from the Gulf Stream, it has a slower motion, its warmth is not so strongly contrasted with the water through which it flows, and the wind blowing counter to its course frequently avails to deflect it or even check it entirely.

Whether or no this current reaches the Californian coast is still a matter of discussion among physicists. But "the winds upon this basin are of the system of the passage winds which are developed upon the surface of the earth by the descent from high altitudes of upper currents. In general these winds vary with the latitude from southwest westerly to northwest. It should be noted that these winds begin to appear about the parallel of 30 degrees north and that at first they are practically dry winds, but presenting all the best conditions for absorption."

Mr. Glassford's review of what he technically terms "passage winds," in connection with Pacific oceanic influences, demands careful study. The phenomena he presents make a very important segment of those which control the arid conditions of all our Cordilleran areas. The local use on the coast of the term "trade wind" is deprecated by the Weather Service writer as both misleading and too narrow. He says:

> These passage winds have a clear sweep across many thousands of miles of sea, and in all this course they incur no resistance save such as is caused by convective friction due to varying amounts of pressure within their mass. But the moment they ceased to flow over the sea and begin their course over the continental mass they are subject to violent perturbations and present all the features of turbulent motion, its irregular and rapid changes of pressure, its rapid expansion, its sudden alterations of the saturation constants, and variations of temperature. These perturbations must be examined in the light of mountain influence in general.
>
> The wind drawn in from sea by the general circulation of the atmosphere may be taken to have in suspension the maximum amount of moisture, and * * * to approximate the saturation amount theoretically to be expected in air of a given pressure and at a given temperature. * * * Variations in pressure and temperature caused by possible distant commotions of the atmospheric envelope may change these amounts. Advancing upon the land the air current immediately encounters perturbing influences * * * such as friction upon uneven surfaces, convection caused by radiation from irregularly heated bodies, and vortex motion within the stream.

These are liable without regard to surfaces. There are also perturbations due to planes which are at a considerable angle with the horizon, and in addition there are the development of pressure by transformation of the impact of the air current upon the elevating plane, the loss of temperature by elevation, the alteration of pressure, and the expansion due to the same cause and the great diminution in the amount of water which may be held suspended. "There is further to be taken into the count the variation of the mountain influence, due to alterations in its radiation of heat. This variation is seasonal. It is due largely to the existence and the melting away of snow bodies. In the first place "the disturbances are at their minimum and so is the precipitation." With the melting of the snow the exposed mountain surface becomes absorbent, and therefore an active radiating agent. "The air current becoming violently involved, is suddenly drawn to great height by updrafts." Then its excess of moisture is 'wrung out' by ensuing expansion. When this sets in on the Sierra Nevada it is dependent upon the sun's southerly movement with such local modifying forces as may be ascertained. The great valley is one of the primary disturbers in the passage of the air currents over the Coast Range from the ocean to the Sierra Nevada. An aërial column moving horizontally against a vertical barrier, that is, a mountain mass, would naturally divide right and left when it had reached and commenced its movement along the face of the barrier. In this way the great valley obtains the circulatory air currents which is one of its special features. These eddies and whirls produced by the impact with the mountain slopes and summits largely distribute precipitation, making a windward fall. That to the leeward of the range is determined by the rise of the currents and their passage over the ridges. In other words, according to Mr. Glassford:

> On the weather side of a high mountain range the moisture is largely precipitated before the elevation of the summit is reached and thus there is absolutely little left to drift over on the leeward side. The second fact is that the small amount of rain which is condensed at altitudes sufficiently high to allow it to drift past the condensing summit is subjected to influences which have a tendency to still further reduce its amount as to falls. * * *

The Pacific Ocean "passage winds," before being drawn .to the surface at about the thirtieth parallel of longitude, have held their course in extreme upper atmospheric conditions, where "excessive cold and tenuity have served to remove their vast humidity," so that when they come to the ocean's surface they are practically desiccated. The moisture they then receive comes from the ocean itself.

Mr. Glassford says:

> The sea is warm and in the best condition for giving off moisture, the wind is most receptive and the amount of humidity which it will assume is mainly conditioned by the distance through which it passes over water surface. In the region where the wind prevails with southwestern inclination this distance may be easily determined and will serve as a means of comparing the average amount of moisture received by places on the Pacific coast.

The theoretical consideration presented by the Weather Service writer, is that a dry wind will assume a certain proportion of moisture from every mile of water surface traversed." Though an efficient general rule, it is, like all meteorological conditions, liable to be affected by local and temporary factors. Still, the records of annual precipitation show that the general principle stated exercises a steady influence. The local and temporary are naturally obliterated in long-time charts, while the general and secular remain as the marked results of the North Pacific passage wind. Mr. Glassford tabulates five coast stations, San Diego and San Francisco, in California, Westport, Columbia Bar, and Tatoosh to the north. Their latitude and relations are, respectively, 33 degrees N., 252; 38 degrees, 672; 40 degrees, 846; 46 degrees, 1,350; 48 degrees, 1,524. The "humid constitution" of the winds are given. For San Diego, annual rainfall measured 10.26 inches; San Francisco, 23.80; Westport, 37.84; Columbia Bar, 67.68; Tatoosh, 94.42. There is an excess between the measured and "theoretical" rainfall, that is, the amount as estimated by the traveled space of the passage wind; (excluding San Diego), as follows: 3.49 inches, 3.36, 12.69, 32.45. The increment is observed to be progressive with increase in northern latitude. The fact is of considerable significance, but the materials for determining its causes are very scanty.

> But [continues the expert] one thing is certainly known because universally observed, and that is, that within the zone of the passage winds across the great ocean the wind hauls westerly in close ratio to the latitude. The wind which moves the rain upon the northern Pacific coast is then not rigidly a southwest wind, it blows from nearer west, traverses more water, absorbs more moisture, and precipitates more rain, and this is a factor of progressive increment to the north and capable of producing an influence of perturbation. * * *

The curves from 55-inch to 90-inch are all defined in the extreme northern section. The 55-inch affects portions of Shasta to Sierra County and then crosses westward, entering the sea to the north of Mendocino. The 60-inch curve enters by way of the Klamath Valley from Oregon and passes out at Trinidad Head. The highest curve. 90, is directly caused by the presence of Shasta, and with those of 82 and 87 affects the areas just below the mountain and passes out to the sea about Crescent City, on the coast. As Mr. Glassford expresses it, from these summaries "it will appear that the least rainfall is upon the Colorado Desert in extreme southeastern California, and the greatest is correspondingly extreme in the northwest; that Nevada, the Great Valley, and the southern coast are the regions of insufficient rain; that the fall increases progressively with height upon the Sierra Nevada, less distinctly so upon the Coast Ranges, and upon the northern coast the increase is more with latitude than altitude." One notable phenomena needs referring to. It is evident that the powerful Cordilleran influence, which, as "guide planes" for aqueous atmospheric currents, must so powerfully affect precipitation and distribution, are yet without effect at certain maximum periods. This is notably true of California. The weather-service writer says:

> The only explanation possible is that the air thus elevated is too dry to precipitate moisture; that its absolute humidity is so low that when the mountain has cast it up to the greatest height within its chimney of convective influence, when it has reached the lowest temperature, the lowest pressure and the highest degree of expansion, the humidity is still below the saturation point predicated on those factors, and no precipitation can occur nor even a cloud form, and those who, from the parched and baking valleys, look toward the shining Sierras, know that the white cap is snow, not cloud. This influence, then, is permanent; the change is in the moisture of the air. Yet as there is equal permanence in the power of dry air passing over leagues of sea to absorb moisture, it is not supposable that this natural force is extinct during certain months of the year and efficient during certain other months, for nature does not thus sport with her fixed laws. It is clear that the moist winds and the desiccative mountains do not come together; thus some cause in nature intervenes to keep them apart during the dry summer of the Pacific slope and the more immediate region of the Great Basin.

As to the nature of this cause, Mr. Glassford offers the following:

> Four points are found to be correlated in a mutual influence upon the climate of the continent, three are always apparent, the fourth is sometimes indefinite in either ocean or the regions north and south, where no meteorological stations are situated. These four points are two areas of low barometer. Their positions relative to one another and to the earth beneath determine the climatic conditions of any periods, be it day, week, month, or year. In one group of positions of these four points the storms have an easy sweep to bring rain across the country, in another group of positions every obstacle is put in the path of storms.

These groupings are defined as to "high" and "low" barometers in the annexed concise descriptive paragraph:

> Over every point of earth stands an air column of uncertain height. The weight of this column of air is registered by the barometer, and from the weight an idea is obtained of the height. A high reading of the barometer at the earth is the surface indication of a high air mass overhead. By grouping these surface indications it is possible to form an idea of the upper of the air with high peaks and ridges over the areas of high barometer on the earth and valleys and depressions corresponding to the areas of low barometer. In effect a barometric high indicates a atmospheric mountain, the steepness of whose slope is exhibited by the close or diffuse assemblage of lines of equal pressure, and the barometric low as surely indicates an atmospheric currents which always seek the line of least resistance and therefore must flow in atmospheric depressions. The leeward side of such an air mountain must then be a place of security against the storms, a region of clear weather, and such it is found to be.
>
> The general movement of the storms is known to be easterly; if the valleys extend east and west the storm has a free passage and converts none of its force by beating against obstacles; it carries its severity to all parts of its course. But revolve the axis of the atmospheric convolutions through 90°, place the ridges of high elevation in a north and south direction, and therefore athwart the storm track, the storm is held back by the height, it must follow valleys to the north and to the south until it can find a gentle slope over which it may pass on its eastward course, but shorn of much of its power by the attempt to overcome the restraining conditions.

The two continental "highs" indicated by this writer are placed in March, one over the valleys of the Missouri and Red River (north) northwardly to Manitoba, and the other on the Pacific coast, from about Cape Mendocino southward. The two "lows" are found, on resting on the extreme northwestern coast, the other drawn upon the southern part of the Great Basin, covering most of Nevada and Utah and considerable adjacent areas of Arizona, New Mexico, and the western slopes of Colorado. In April the Missouri high is outlined upon the whole central valley. The Pacific one is strongly accentuated on the coast line. The lows are to the north broadly outlined upon Montana and adjacent British America; to the south it is restricted narrowly to the lower section of the Great Basin and down the Colorado Valley.

Once assumed, these remain "fairly permanent for several months;" for even when some transient barometric disturbances occur, conditions are rapidly resumed. "The harmonic vibrations are confined to the swinging in and out" at the east and north, under the influence of "the eastern high." In May, this has moved over the Appalachian heights. In June, it swings back upon the central valley and the accompanying low "is found across Montana, North Dakota, and Minnesota." The July movement carries the "high" still farther east, resting upon the south Appalachian range and their regional coast line of Atlantic and Gulf. Again in August it is carried back into the lower central valley and loses its type character. At this time the North Pacific "high" begins to encroach upon the land. The eastern pendulum has ceased its movement. That now spreads out along the whole Atlantic coast. The northern "low" is again seen over Manitoba. The southern appears to be restricted to the Colorado Valley. The Pacific "high" in September is seen to overlie Washington and Oregon, with adjacent portions of California and Idaho. There is little change in October, except a "drawing together of the two highs." The low remains for September and October—north over Manitoba, south over the lower Colorado. The Pacific "high" is further inland and the eastern is drawn over the whole Mississippi Valley. The four forces are again in "expectant" poise. November discloses the waiting movement. "The climatic constants have been moved in longitude; they are eastward by 20 degrees of arc. Upon the Pacific coast the "high," which began to creep upon the land in August by almost imperceptible movements, now rests upon the Great Basin, and extends over southern Idaho and northwestern Colorado. The "concomitant lows appear north and south upon the Pacific coast, on western Washington and northwest Oregon, and on southern California, respectively."

Thus far has been seen a season of typical movement followed by a brief transitional rest, to be succeeded by a second type equally cosmical and permanent. November conditions endure to January; the "high persists upon the Great Basin; the low on the Pacific remains permanent in western Washington; the second low on the Pacific has a progressive eastward motion of slow rate." The February change is only in the Pacific southern "low," which has definitely moved eastward to the Colorado Valley. March rounds out the year. The "low" just named has moved over the southern section of the Great Basin. The eastern "high," which has been quiescent, moves west as far as the Missouri Valley, and the high that has rested over the Great Basin recurs to the Pacific coast. It is these recurrent operations that condition the whole climatic phenomena. The summers upon the Pacific coast and the Great Valley are alike defined by the two high barometrical areas. The Pacific winter is defined by a "high," in the Great Basin, and two "lows" upon the coast prevailing from November to March, a period of five months. The summer type is that of most persistent drought, the two transition periods, September and October and March, are mixed, rainy or dry, according to conditions just preceding, and the winter type is that of the greatest rain fall.

The economic effects of these conditions are of the utmost importance to both ordinary and irrigation agriculturist. With the flow of mountain streams and river valleys in the region of Cordilleran topography the hydraulic inquirer is most directly concerned. So also with the practicability of storage of storm waters, or their recovery as phreatic and artesian flows. The broad factors indicated in the preceeding summary of the most important and comprehensive review of our permanent continental climatic conditions yet prepared, are three: The pelagic or ocean currents, bearing a vast aqueous flow to the Pacific coast; the great mountain formations against which these aqueous currents precipitate themselves, and finally, the barometric conditions that permanently arise and recur as a result of altitude and latitude, making seasonal distinction and producing dynamic forces which inincrease or decrease the effects produced by the static conditions of mountain planes and elevations. Certain broad and economic outlines are naturally projected by such a sweeping study. They can only be indicated at this place as guiding points for further inquiry. The precipitation which falls upon the earth is either carried off and down by surface channels which have been eroded through preceeding currents or it leaks into the earth itself, to reappear below as springs, and rise when tapped as artesian flows, or to come again to the surface when intervening stratum are opened or removed so that by gravity or lifting by mechanical means there may be assumed and obtained a restoration of rainfall that has been stored phreatically as it fell from clouds to earth surfaces. Of the precipitation, then, there is loss by sinkage, seepage, and imbibition, or by evaporation. The latter is without recovery; the other may, as indicated, be restored to the uses of man, at least to a large degree.

Evaporation in California, as elsewhere, is a matter of importance in examining the availability of precipitation for purposes of reclamation and cultivation. The provisional curves constructed from the observations already made indicate the neighborhood of Owens Lake, Ingo County, as showing the maximum curve of loss; that is, 100 inches. The 90-inch curve enters the State as a narrow loop at Yuma and is drawn along the eastern base of the Sierra Nevada until it recurves southeastward just above Owens Lake, and reënters Arizona across the Nevada plateau at Mojave. The 80-inch curve follows very closely the preceding one, projecting northward in Nevada as far as Winnemucca. The 70-inch curve follows the southeast mountain flanks and the southeast deserts of Nevada, and at Lake Tahoe swings northeasterly into eastern Oregon. The 60-inch and 70-inch curves belong to the great valley and are drawn upon the southern coast range along its extreme length till it passes north. The 40-inch curve follows and parallels the range and coast lines.

These factors bring the discussion to direct consideration of climate and weather. The two controlling superficial factors of ocean winds and massive mountain barriers give for California and Nevada "a climate which differs from that of any district within this country and which, practically constant as a whole, displays equally constant differences between the several natural districts into which the region is divided." There is also to be considered the fact that as a whole the region has its own distinctive climate, which is thus described by Mr. Glassford:

> The distinguishing characteristic of the climate of the region is that varieties of weather endure practically unaltered for days at a time, and even when supplanted by others return again and again, and on each such recurrence are symmetrical with their

former appearance, even when they are not practically identical. In this regard there is a wide variation from the conditions which obtain elsewhere in the United States. Nor is this the only difference. Another notable one is that the storms of the Pacific are with comparative infrequency traced across into the Central Valley and the Atlantic slopes. Another is that storm frequency increases rapidly towards the north.

The storms referred to are seldom felt below Cape Mendicino on the coast, while bringing rain to the San Joaquin Valley and as far south as San Luis Obispo. The southern part is untouched except by a "low" sometimes briefly developed in Sonora, New Mexico. Light showers occur from San Francisco northward, when there is a low shallow area over the North Pacific in the latitude of and not far from Washington. This rain seldom passes south of San Francisco. Low pressure then over Oregon and Washington results in rains over northern California when however a high area rests upon the two northern States. Quoting Mr. Glassford, we find that:

> The low type is permanent over Southern California. * * * A diffused and moderate "high" on the southwest coast is accompanied by an unusually low temperature. During this condition rains fall in the Los Angeles region and southern portions of the great valley. A considerable general fall occurs with a retaining "high" barometer on the southwest coast and heavy gales, hail and thunder storms may result. Local rainfalls are marked by a moderate "low" continued for several days and below the normal "over a large area."

Mr. Glassford continues:

> The dry season shows little variation from beginning to end. Rain is almost entirely absent and the light showers which sometimes occur on the Washington coast only rarely drop down upon a limited district of the California coast. Another feature of the season is the development and persistence of marked intensity of the "high" in Oregon accompanied with a corresponding fixity of a slight low area over southern California, creating the characteristic northerly winds which blow down the great valley.

A study of the rain curves shown in California as well as Nevada is one of great interest. Mr. Glassford puts the line of arid demarcation at 20 inches of annual precipitation, an estimate which this office accepts as reasonable. The whole of Nevada below its Sierra summits is within the Great Basin region and below the 20-inch curve. It is affected by a 5-inch curve which crosses the Mojave Desert and extends over the 3,000-foot plateau of western Nevada as far east as to include the Carson and Humboldt lakes. This curve in a narrow belt also crosses northeast Nevada and penetrates Utah to the extreme northwest of Salt Lake. A 10-inch curve peculiar to the Great Basin enters from the east, between latitude 37 and 38 and moves westerly across Nevada to a point beyond Pyramid Lake, where it turns southwest and moves until it is lost under the influence of the Colorado Desert dessication. I quote:

> In eastern Nevada a narrow loop of 15 inches clings to the north and south valleys of the White Pine ranges from Pioche to Fort Halleck. The general 15-inch curve of the Great Basin enters upon the northern border at Fort McDermitt, sweeps eastward to include Tuscarora, and then swinging sharply back along the upper edge of the basin parallels the 10-inch curve of the same system upon the eastern Sierra face as far as the heights which break away above the Tehachpi Pass.

It then descends the Sierra slopes and enters the great valley to be lost on its lower plane. The lowest rain curve (3-inch) in California enters at Yuma and controls the Colorado Desert. The 5-inch curve follows the river on its eastern edge, passing northward to the Mojave Desert, reentering it at Daggett and curving southward again to the river at the Needles; thence it enters Nevada as already stated, extending northeast to the Humboldt.

The 10-inch curve and less appears in the lower portion of the San

Joaquin Valley, again along the San Diego coast, the Upper Santa Ana Valley, and at the junction of the San Joaquin and Sacramento rivers. The 15-inch curve which enters from the Great Basin rises along the heights which break away to the east of the Tehachepe range, in southern California, enters the great valley, and at once seeks the lower contours, coming out into the level plains at Fresno. To the north it marks the controlling influence of Merced, Stanislaus, and San Joaquin counties, going north to the slough region of Sacramento, Solano, and Contra Costa counties, and then climbs slowly south and to the west of Lake Tulare, where it marks the line of dry currents from the San Joaquin Valley and the desiccated one from the Colorado Desert. The 15-inch curve is marked also upon the eastern slope of the Coast Range, along the 1,000-foot contour of the Santa Ana, and sweeps around the 10-inch curve. It is also seen in Salinas Valley and San Benito County, as well as in the Sacramento Valley, Colusa County. The 25-inch curve enters from Oregon about the center of the northern boundary and moves east and southeast to Sisikiyou, Shasta, Plumas, and Lassen counties and beyond as far as the head of Kern River. Returning north it follows the foothills, seeking and modifying the lower level curves, until Red Bluff in the north is reached; thence it recurves, taking the Sacramento Valley southward, round the Sonoma Valley, and into the Bay of San Francisco. The neighborhoods of Ukiah and the Upper Russian River are under its influence also. It runs southward along the Coast Range heights, reaching Mount Julian, where the rise is upward to 35 inches. From there the general curve of 25 moves across Ventura County. It affects the coast from San Benito to Mount Hamilton, has a place on the southern portion of the San Francisco peninsula, and over portions of the bay region in Contra Costa and Alameda counties. The 30-inch curve follows, but above, the general direction along the higher Sierra of the preceding one. Its southward limit is the head of Kings River, where it turns north, along a lower alignment being drawn into the Sacramento Valley as it moves north. At Shasta it recurves and moves along the inner slopes of the Coast Range southward to San Pablo Bay, passing out to sea at Mount Tamalpais. All of the remaining curves are confined as to influence to northern California. The 35-inch is mainly confined to the vicinity of Redding. Higher curves follow alignments, showing higher latitude and low altitude, thus proving their entire dependence for regulation upon the ocean currents of the north Pacific, as already mentioned in this summary. The 40-inch and the 45-inch curves are found aligned along the headwaters of the Tuolumne and Stanislaus rivers, passing westward up the Trinity and through Round Valley, leaving the land south of Cape Mendocino. The rapid increase at certain seasons in the flow of the rivers named is due to the large precipitation shown. This is a matter of grave importance, as it insures the permanence of great irrigation supply which has hardly been drawn upon. The water storage of the important Turlock and Modesto districts is directly related, it will be seen, to the 40 inch and 45-inch curves, which, as precipitation in either rain or snow, feed the notable mountain river at whose debouching cañon mouth the storage dams of the two districts named are now in process of construction. The irrigation districts in Colusa County are also endowed with secure sources of supply. It is quite a reasonable estimate, then, to regard the mountain streams of central and northern California as capable of furnishing water sufficient to irrigate four or five times the number of acres now under such cultivation in the Golden State.

California presents the oldest as well as the best example of farming by irrigation within the United States, as it does the most fascinating of physical conditions. The Franciscan Fathers partially systematized irrigation a century ago, and when their semi-municipal control of the Indians was absorbed by the Mexican Government, followed as it was by the American conquest, the art (relegated to the care of the Indians and Mexican land grantees), was practically ignored.

During the American settlement incident to the gold excitement agriculture had little place. The necessity of a permanent food supply for the growing population was soon brought to the front, however. But the wide-stretching acres of the great wheat ranches alone yielded profit, and there were many reasons for this, because, while production was limited to staples giving small returns, $1 an acre with an indifferent culture on a 10,000 or 20,000 acre ranch represented a greater profit than $5 or $10 per acre to the small but careful farmer. An early report of the State Agricultural Society says:

> We have within the geographical limits of California over 100,000,000 acres of land, of which less than one two-hundredth part is under cultivation.

A system of crop culture that afforded the product of only 500,000 acres of poorly tilled land (1862) for the support of more than that number of persons could not stand.

According to Engineer William Ham Hall, in 1852 a band of Mormons from Salt Lake took possession in San Bernardino of some old mission works, bought a Mexican rancho there and commenced irrigation, which was probably the first noteworthy effort made by other than Mexicans; in 1856 some Missourians diverted water from the Kern River in that county ; in 1858 the water of the Cache Creek in the Sacramento Valley was taken out, and in 1859 a little water for irrigation was developed from Kern River. With so little of the arable lands irrigated and such large tracts sowed to broadcast crops, the introduction of a system whose very essence is intensive cultivation was a difficult and disheartening process. The employment of unskilled labor on an irrigated tract counts the loss of from 30 to 50 per cent of the crop. The land requires constant care and the crops the utmost watchfulness. In an irrigated region the small farm seems to be a logical sequence of the system. Besides this, under Spanish-Mexican law, water for irrigation is held to be subject to beneficial servitudes, or it might be expressed "to run with the land." The mining settlement gave shape to the agricultural control of water for cultivation, and prior appropriation was the rule almost wholly among those who farmed and made homes. The stockmen, the sheep rancher, and the speculative landowners were commonly advocates, on the other hand, of riparian rights. This did not become a marked issue until irrigation and colony life grew into a vigorous economic factor. But the whole plan of prior appropriation, though generally supported by the court, was a shiftless affair. No rule for its government was laid down ; no supervision was provided for or enforced. The legal requirements were simply that the claimant of water for irrigation should post a notice of appropriation at the point of diversion and within sixty days thereafter begin the construction of his works. Usually a copy of the claim was filed at the county seat, but no State or municipal inspection or measurement was provided, nor were the records properly preserved. The claims were generally couched in very indefinite terms, being worded by the farmers and corporations immediately interested. The development under this loose administration and acquisition of water rights was very slow, capital was wary, and the peculiar feature of this indefinite period, down to the adoption of the irrigation district system is, that progress was greatest in those regions presenting greatest natural obstacles, as in the difficult southern counties rather than in more favored basin plains, owing to the greater security of absolute proof of prior appropriation and beneficial use. In early irrigation the object was to get water to particular tracts owned by the appropriator, and not to put it on the most available land, which in most instances was more convenient to the head gate of the canal.

For example, in the San Joaquin Valley four large canals now pass within 2 miles of Centerville, in Fresno County, at equal elevation and commanding the same territory, the waters of which are directed to unrelated tracts of land. One canal of greater capacity than all four combined would command a larger and more compact territory at much less cost. In 1870, the real development of the water resources of California began. The Commission authorized by Congress, under a resolution of Senator Stewart, of Nevada, in 1868-'69, to investigate the San Joaquin Valley, endeavored to prove that there was a permanent and sufficient water supply to be found there for the irrigation of large areas. That report, as well as actual cultivation, showed that the rich soil of valley and plains were among the best lands in the world for extensive and diversified agriculture. Under a notice claiming "right to construct a ditch 10 feet wide, 1½ foot deep, or to a volume of water of 2,160 inches," posted July 5, 1865, the Centerville Canal and Irrigation Company, in 1868 and 1869, built an irrigation canal, using Centerville slough, one of the channels of King River, thence south and west to Burns Slough, another natural channel, which was utilized, and thence to the lands served in the vicinity of Centerville, on August 5, 1869. The water right of this ditch was enlarged under a location of J. B. Sween, "from the margin of said river (King's) 10 feet wide at bottom and 2 feet deep under a 4-inch pressure." In 1870, M. J. Church and A. Y. Easterby entered upon the Fresno Canal and Irrigation Company's project to appropriate at the head of Sweens Ditch, "water to be taken from King River at the upper end of Sweens Ditch, 20 feet at bottom and 30 feet on top, and 4 feet deep." In 1874, this company acquired all the rights of the Centerville and Sween Canals. The Fresno Canal and Irrigation Company was the first illustration of irrigation on a large scale in the United States, being a short period in advance of the famous irrigation colony at Greeley, Colo. Many vicissitudes marked its early history. Messrs. Church & Easterby becoming involved in financial difficulties the canal passed under control of the Nevada Bank, but it failed to pay dividends and after a time was sold back to Mr. Church, and since then has remained under the management of the company of which he is president. When the waters of this canal were first poured over the land the soil was powdery and dry to a depth of 50 to 90 feet, and absorbed water like a sponge. In order to get the water to run a full head was allowed to flow into the ditch for a short distance; it was then shut off and permitted to settle and deposit its load of silt. The bed of the canal would thus present a smooth, glassy appearance, and before the film of sediment cracked in the sun a new flood was let down to the next dry section. The sediment thus formed had the tendency to puddle the bed of the canal.

Before noticing more fully the irrigation in this region, a glance at the topography will help to better understand the subsequent development. The San Joaquin Valley is a vast intramountain plain, extending north from the Tehachepe Range to the junction of the Sacramento and San Joaquin rivers, and east and west is walled in by the Sierra Nevada and coast ranges. The San Joaquin River carries off its drainage. It comes out of Sierra midway in the valley, picking up at Las Juntas the surface flow from Kern, Tule, Keweah, and King rivers. All head in the eastern range and debouch on the plains, resembling the skeletons of four leaves laid side by side, the stems in each case being the main or cañon stream and the delta being the frame of the leaf. In the southern end of the valley enormous precipitation is poured down from the Sierra without forming a permanent water way. Tulare, Buena Vista, Kern, and Goose lakes are the only evidences of this vast flow, but even they have no constant outlet towards the San Joaquin River, other than a series of swamps and tule beds. The soil before irrigation was dry below the reach of suction pumps. The eastern side of the valley is well watered, but on the western or coast range side there is scarcely a stream perennially flowing into the San Joaquin Basin; certainly not a single one below the junction of that river and the Merced. The irrigation has naturally been on the eastern side of the valley. Some effort is now being made on the western side. Twenty-five years ago the San Joaquin Valley was only known as a dreary stage in the journey to the mines of the Sierra Nevada mountains. Bakersfield, Visalia, Fresno, and Merced were simply hamlets. The canals that have filled the land with plenty were only dreams of students and visionaries. The stockmen held supreme control over the foothills and plains, and their opposition to irrigation was violent.

The success which followed the introduction of irrigation into the San Joaquin Valley stimulated exertion elsewhere, and the practice was improved on in the six southern counties, which latter, owing to the large profits on their products, have become the best-known irrigated region in the United States. The open canals have been often described, and that need not be reiterated. It is necessary, however, to dwell briefly upon one peculiar feature of irrigation in the San Joaquin Valley, viz, the lifting of the water table, or plane, towards the surface. In this region the canals are all constructed for the avowed purpose of allowing seepage into the soil through their banks. The result is that lands on which from $5 to $20 per acre have been paid for the right to use water are now filled to saturation. Drainage is often needed to carry off the constantly increasing soil water. As yet this destruction of the land has not been very general, but it must be reckoned on within the near future. The only danger is that the land may degenerate into a swamp. Engineer Wm. Ham. Hall, in a paper read before the American Society of Civil Engineers, says:

> I saw in 1877 enough water, by actual measurement of flow, put on 20 acres of land to cover it 18 feet deep, in one season, could it all have been retained upon it. It simply soaked into the ground or flowed out under the great plain. Taking cross sections of this country, north and south, east and west, I found that where the depth to soil water had, before irrigation, been about 80 feet, it was then 20, 30, 40, or 60 and more feet down to it. The soil water stood under the plain in the form of a mountain, the slope running down 40 to 50 feet in a few miles on the west and north. On the south and southwest the surface of this water mountain was much more steep. In the Kern River country we have a somewhat similar phenomenon. Irrigation, in the upper portion of the Kern delta, affects the water in the wells 6 or 8 miles away. As I remember, the effect is felt at the rate of about a mile a day; that is to say, when water is used in irrigating the upper portion of the delta, or of Kern Island, as it is called, the wells commence to rise a mile away in twenty-four hours, and five miles away in perhaps five days.

It is claimed that the more water in the soil the better it is for the irrigator, as it is not only preserved without loss by evaporation, but tends to more constantly feed the rivers, whose flow during the dry season has greatly increased since the introduction of irrigation. Mr. J. P. Vincent, of Fresno, Cal., speaking to the special agent on this point, said:

> The fruit area of Fresno County is increasing, and will continue until all available lands are put under cultivation. In the early days we said we had 7,000 acres of irrigable land, and outside of that nothing; but now we have 7,000 acres that are drained in order to raise crops. For the old vines we use very little water, but for the new ones we use very large quantities, as the desire is to saturate our lands. The vineyards are extending principally towards the foothills. Wherever we put water we plant crops, but we are extending towards the foothills, because the soil is heavier and freer from alkali. The best part of our wheat is raised in that direction. If we used our water at the proper time we could irrigate even more land than we now do. Our supply is sufficient for all purposes, and we have not yet considered the question of storage. In winter we can flood our land 4 feet deep, and thereby save irrigation in the low-water season of summer. Our object is to fill the land, and instead of having it 60 feet below surface, we want the water plane to be from 6 to 8 feet only. In the vicinity of Fresno, northeast to the Enterprise Colony, the water plane has risen to within 30 feet of the surface. In some places it is less. Along the lines of the canals there has beeh without exception a general rise. This has enabled us to extend constantly the area of planting from a surface supply, originally considered very inadequate. There has been quite an extensive increase in the planting of vines and trees during the winter and spring of 1890–'91.

J. C. Shepard also described the method of using seepage water for subirrigation.

> The duty of water is now supposed to be 1 cubic foot per second to 160 acres of land, but if you take into account the amount of land planted to vineyards and orchards, not watered at all on the surface, but made fruitful through seepage subirrigation, it will be somewhat more. These lands receive their water, by percolation, from the ditches under which they lie. There is an impression that we run a ditch around a thousand acres or so and allow it to seep up, but this is not so. We run the water right on the land wherever we irrigate at all; the nonirrigated only receives moisture from the seepage of the wet lands or from the ditches. The greater part of the country east of Fresno, between here and Kings River, where vineyards have been planted, is not irrigated at all. Some of these vineyards have never been irrigated, and there are no ditches on them. The only water they get besides rainfall is through the seepage of the main ditch. The country falls to the south and west, and the surface water has risen from a depth below the reach of suction pumps near enough now to the surface to supply the roots plant. The effect of this seepage is very noticeable, because the country is full of depressions, which have filled with water and are covered with tules. This is seen for a distance of 25 miles or more south and west from Fresno. Farming in this region is now carried on under much more favorable conditions than when our colony life began. Water for stock is more easily obtained, and while the ground water has not risen high enough for grain, still many crops are greatly benefited, among which is alfalfa. It grows in many instances without surface watering.

The following tables of water loss from canals were made by Mr. C. E. Grunsky, ex-assistant State engineer of California, during his official investigation of the region under consideration. These tables, with other valuable material in part incorporated in this report, have been received from Mr. Grunsky for use by the office of irrigation inquiry. The abolition of the State engineer's office has prevented the further prosecution of these important observations:

Loss of water from the Kings River and Fresno Canal.

[Measurements by C. E. Grunsky, assistant State engineer.]

Name of canal or ditch and locality.	Distance below head of canal.	Discharge (cu. ft per sec.).		Loss between stations (cu-ft.per sec.).	
		Main canal.	Diverted.	Total.	Per mile.
	Miles.				
K. R. & F. C., one-half mile below head	0. 50	133. 83		43. 36	3. 77
Burns Ditch	1. 00		0. 25		
Hansen Ditch	4. 00		3. 23		
Fanshaw Creek (wastage)	8. 00		0. 30		
Ditch on south side	8. 00		4. 05		
Ditch on south side	9. 00		0. 05		
K. R. & F. C. at Hawkins Weir	9. 00	*78. 18			
Wastage			0. 15		
Ditch on south side	11. 50		2. 04		
K. C. & F. C. in Red Bank Creek flume	12. 00	80. 40		16. 50	3. 48
Dog Creek (wastage)	13. 25		0. 15		
Ditch on north side	16. 00		3. 36		
Eggers Ditch	16. 75		4. 67		
K. R. & F. C. at Eggers Weir	16. 75	55. 72			
K. R. & F. C. west line of section 17	17. 75	*49. 56		4. 44	1. 25
Ditch south side	17. 80		3. 08		
Scand. Col. Ditch	18. 25		3. 86		
K. R. & F. C. at upper Scand. Col. Weir	18. 25	*36. 74			
Scand. Col. Ditch	18. 35		1. 46		
Scand. Col. Ditch	18 50		2. 42		
Scand. Col. Ditch	18. 60		1. 00		
Scand. Col. Ditch	18. 70		2. 39		
Scand. Col. Ditch	18. 80		14. 50		
K. R. & F. C., Lower Scand. Col. Weir	19. 00	*21. 51			
Big Creek (wastage)	19. 25		1. 50		
Wastage			0. 20		
Ditch on north side	19. 75		0. 43		
Cooper & Helm Ditch	20. 25		8. 71		
K. R. &. F. C. at Cooper Weir	20. 30	11. 73			

*Approximate.

Loss of water from the Fresno Canal.

Name of canal or ditch and locality.	Distance below head of canal.	Discharge (cu. ft. per sec.).		Loss between stations (cu.ft.per sec.).	
		Main canal.	Diverted.	Total.	Per mile.
	Miles.				
Fresco Canal at Road Bridge	1. 25	381. 00		95. 51	8. 49
Centerville Branch	1. 75		17. 80		
Lone Tree Branch	3. 25		69. 39		
Ditch on south side	5. 00		0. 50		
Limbaugh Dam Ditch	12. 50		58. 72		
Fresno Canal at Limbaugh Dam	12. 50	139. 08		5. 20	0. 74
Briggs Canal	14. 00		0. 30		
Eisen Canal	14. 00		14. 09		
Fresno Canal at Hobler Dam	14. 00	*107. 88			
Easterly Ditch	17. 25		5. 60		
Malters Ditch (North)	19. 00		6. 30		
Malters Ditch (Central)	19. 00		1. 69		
Washington Col. Branch	19 50		45. 50		
Fresno Canal at head of Wash. Col. Branch	19. 50	60. 40		3. 81	0. 95
Fresno Colony Canal	23. 50		14. 15		
North Central Col. Canal	23. 50	28. 16	13. 88		
Main Central Col. Canal	23. 50	28. 16			

*Approximate.

Loss of water from the Centerville and Kingsburg Canal.

Name of canal or ditch, and location.	Distance below head of canal.	Discharge, cu. ft. per sec.		Loss between stations.	
		Main canal.	Diverted.	Total.	Per mile.
	Miles.				
C. & K. canal, ½ mile below head	0. 50	346. 00		85. 94	15. 63
Ditch on west side	5. 50		5. 06		
Do	5. 75		4. 00		
C. & K. Canal at Wier, in sec. 23	6. 00	251. 00		52. 35	52. 35
Garfield Canal	7. 00		26. 65		
C. & K. Canal at Wier, in sec. 26	7. 00	172. 00			

The loss by evaporation on the Fresno Canal, throughout its 24½ miles of main canal, as arrived at by the same authority, from observations extending from 1881 to 1885, was equal to a continuous flow from the ditch of 2.8 cubic feet per second for the total length.

The humus or vegetable mold of which the soil of the southern end of the San Joaquin Valley is composed, in connection with its arid climate, has a tendency to "bloom" out in alkali, a prevalent form being what is known as black alkali. Underdrainage, however, is the natural corrective of alkali eruptions on the soil, and a local system of irrigation drainage must therefore be adopted. It is certain that with care the alkali will quickly cease to be a source of uneasiness. Irrigation must in the very nature of the art be the result of associated effort. The first large canal, as already described, was taken out by a private corporation, and the water contracts of this company, with its irrigators, called for a pro rata share of the water in the ditch. This clause was soon taken advantage of for the formation of colonies, by which a body of persons desirous of enjoying the advantages of associated effort organized for mutual assistance in the building of ditches, etc. The locations these bodies made are among the most prosperous in California.

As an illustration, in the San Joaquin Valley land values have advanced from less than $5 per acre for land without water to $200 and $250 for land with water. In southern California and all the citrus regions the price of watered land is double that of San Joaquin areas. Speculation in land and water rights aimed till recently to make the latter a personal franchise rather than an easement of the land. The right of prior appropriation was pushed to the uttermost, and in the conflict that ensued from 1870 to 1885 the courts were burdened with the suits of water-users, water-owners, and those between rival companies of owners. Such was the state of affairs at the time of the introduction and passage of the first Wright irrigation district law. The several laws, so known, are an effort to give the highest legal sanction to the permanent union of the land and water, but at the same time to recognize every other existing right and equity. The question with the people interested was the method of union. It was common sentiment that some such course was necessary, but the ways and means were the vital question. At an interview between the special agent in charge and Mr. C. C. Wright, the author of the present district laws, and Mr. Nance, the president of the California State Association of Irrigation Districts, Mr. Wright expressed himself as follows :

> I was elected to the legislature for the express purpose of advocating some measure providing for the municipal control of water for irrigation. In devising plans it occurred to me that the best method whereby the people could organize, and when organized would have power to assess and collect money for the purpose of construct-

ing works by the ordinary process of levy and collection, was the proper thing, and that a local government based on the familiar lines of county government and officers, differing in no respect from such an organization, except in the object to be attained, would accomplish our purpose without chance of failure. So, this district law was formed with the object in view that there might be created a special government for the one purpose of developing and administering the irrigation water for the benefit of the people. The idea was to organize a local government for this purpose and the single object of providing works and paying for their construction; and it seemed to me best to adopt a somewhat more limited municipal organization than that of the counties, or a municipal organization for one purpose only. There was nothing new or novel in that plan. The district when effected is the same as a county. It has its board of directors as the county has, its board of supervisors, and assessor, treasurer, and all other officers necessary, within its municipality, whose duties within the district correspond to the duties of similar officers in counties. The proper county officials are empowered to provide for the construction of any needed work, such as a jail, court-house, bridge, road, etc., and to do it by direct assessment; but if the cost is too great for that method, by an issue of properly authorized bonds. It is just the same with an irrigation district. The board of directors were given the same general power to construct a system of irrigation works as is given to a county.

Then, as to the method of community association or election in a district, I thought again that the mode of forming municipal bodies in this State should be followed. The legislature can select a municipality or district by direct act, but there must first be a petition from a certain number of freeholders; and then there should be an examination by a board of supervisors, who could employ engineers, etc., to report upon the formation of the district, and they should have every facility afforded them to make a thorough and exhaustive examination into the propriety of forming the district. When satisfied as to this they should be authorized to fix the boundaries and propose to the people whether the district should be so organized; and after such a proposition has been made with sufficient notice, if the vote of the people showed two-thirds in favor of forming the district, then that vote should operate as the act or fact which should result in the formation of the said district.

First. The formation is provided for the same as other corporations in the State.

Second. When the district is formed the plan is to be carried out on the lines similar to those upon which county government is laid down.

Third. The plan for raising money is the same as that of a county. The board of supervisors make assessments to construct a work, and, just so, the directors make an assessment and submit it to a vote of the people for an irrigation ditch or reservoir; they make specifications and advertise for bids under the system of competitive bidding, and award the work to the lowest bidder.

Another thing is that if the district should be compelled to issue bonds when the amount needed be too large for direct assessments, a proposition to vote bonds may be submitted; if that prove insufficient another proposition may be submitted and a second issue voted, but the directors are empowered by law to levy a direct assessment and complete the work. This power is granted in order that the work may not be commenced and then allowed to remain unfinished.

As to the obstacles to setting these districts on their feet, the only important one has been the lack of confidence in the bonds. They are a new security. Everybody acknowledges that the decisions of the Supreme Court have set at rest all legal questions involved; but yet it has not done away with the feeling that these are new and unproved securities. Capitalists are slow to take them. There has been some opposition of a pronounced character from the large land-owners who have a notion that they owned not only the land, but the water and the people also, and they will antagonize any attempt on the part of the people whereby they may become entitled to any part of the water. The large land-owners want the water themselves, and they do not want cultivated lands brought in competition with their own. As to the question of taxing lands because their value is increased by the irrigating ditches, I think that is best handled by our system of assessment and equalization, which is the same as the county plan, and I have studied that plan a great deal. There is nothing in the law to prevent all lands being assessed at the same figure. It might all be assessed at $50, for in such cases the land is supposed to be intrinsically of the same value. Then the board of directors, sitting as a board of equalization, will finally settle the question, and poorer land be assessed at its proper value. If, on the other hand, you make a cast-iron rule that the poor acre would have to pay as much as the good acre, it would be wrong, but the equalization makes that all right. There is no reason why the system should fail because the assessments are equal; and experience has shown that there is no reason why a district may not carry on a complex system of irrigation. The canals and their administration is as natural to the district as the building and management of highways is to the country.

As to the public or government lands within the district area, I think it would be the proper thing for Congress to pass an act making them liable for cost of district works. The holder of such lands must take them subject to a lien for the improvements. I know that there are many people who have delayed taking out their patents in order to escape paying water assessments. As it is, we have gone ahead and entered the assessments, and when the owner of such lands wants water for them he will have to make some equitable arrangement in regard to the expense of the works and other details. On the mere basis of benefit to the public lands Congress ought to authorize a thorough investigation into the district system, the feasibility of its operation, source of supply, character of soils, and character of security it offers for investments. This would serve to promote irrigation interests all over the country.

Mr. Nance declared that:

The great effect of the district system will be to lessen the cost of water to the user at least one-half. In the Alta district of Fresno and Tulare counties the expense of furnishing water, including interest on the entire debt of $410,000, will not exceed 25 cents per acre for the past year. [Mr. C. C. Wright has more recently stated at 40 cents.] Under the old system it was $5 per acre royalty or franchise and $1 per annum for rental. It had been as low as 50 cents, but it was raised to $1. There are no royalties or franchises under the district system. The only cost during the first ten years of the existence of the district is that of interest on bonds, maintenance, and administration. You do not begin the formation of a sinking fund for the payment of the principal of the bonds until after ten years. After ten years you begin to pay back the principal. You might consider it in this way: In the Alta district the amount of money to be expended during the whole period of twenty years, including interest and principal of bonds, is $5.19 per acre. If you consider that as a royalty you will get at the cost of a district system to the irrigators, with the exception that you do not have to pay the royalty in a lump sum, but spread out over a period of twenty years, during which time your land has been yielding a return, and after the bonded debt is wiped out the expense of running will only be 7 or 8 cents per acre.

Mr. J. C. Shepard, of Fresno, in speaking of the district system, said:

The Wright law is a long step toward the proper method of irrigation. It may not be perfect, but it will be very hard to get a law that would be better. Under it the people, or rather the water users, become the owners and controllers of the water, the works, and the administration thereof, paying of course for such capital as they use in the construction of works, the title of water becomes finally vested in the title of the land. This system supersedes and does away with the litigation caused by the conflicting claims of riparian owners and prior appropriators, and the general impression is that it will work out well. As to the question of cost of the system, it is not thought that any man who compares the cost under the district system with that under a corporation will find the results unfavorable to the Wright law.

The large landowners have undoubtedly objected to the formation of irrigation districts because they would have to pay taxes on their land. This fact is apparent in the Alta district, where the large owner says the taxes are so heavy he can not afford to keep them up, and consequently he is seeking to dispose of the land in small parcels. It is either being sold out or the owner is letting people have it to plant on shares. Actual settlement and cultivation have increased the value of this land to $250 per acre. The large landowners have not paid a cent to bring about that increase, but under the district laws they would have to bear their equal share. Another obstacle besides the hostility of such landowners has been in cases like the Selma district, where there are three systems of canals, and it can not be agreed what is to be paid for them. This dispute has resulted in defeating the bond issue proposed. This hindrance has been caused by the ditch systems themselves. The law of course provides for the power of condemnation, but as yet we have not exercised it. I do not think this district will soon vote its bonds, because the directors of the canal companies want the directors of the district to make terms with them and to give a certain amount for their canals, which the district people refuse. Then the ditch owners started in to defeat the bonds and did it.

The general effect of the system when tried is to greatly lessen the cost of water to the irrigators, and when the districts are more unified the cost of administration will be much more reduced; besides this the intense public opinion and watchfulness aroused will be a check on the slightest unnecessary expense.

The views of Hon. J. P. Vincent, of Fresno, who was chairman of the committee on irrigation of the California assembly, during the discussion and passage of the first Wright law, are presented in this connection:

As to the application of the Wright system, I would state that it is much more difficult to apply it to a country like this where systems have grown up, than to a country where there is no irrigation at all. You see in this section, with our numerous systems and farmers under them, many of whom are stockholders in the canals, we are interested in the success of the present methods. If the present canals had only have been larger we could have irrigated much more land with less expense per acre. One of the great advantages of the Wright system is that it makes each man pay his share both of constructing and operating the canal. Now, in our experience we find that one man will not take and pay for water because his land is so situated that he will get his supply from his neighbor's seepage. We have a great many such men.

At the time the first Wright law was passed I was chairman of the irrigation committee of the California legislature. My idea was that we should form "water districts," which should own all the water of a stream irrespective of the construction of the canals. For instance, if a man owned 1,000 acres and there was only one-tenth enough water to irrigate it, he could only irrigate 100 acres. The idea was this, that every acre irrigable by King River, say, had a right to water. The result would be there would be about four times the amount of canal construction and there would be four or five times as much water taken out at the high stages and not so much needed at the low stage, and in that way the country would soon be filled with water and but little would be needed.

The greatest objection to the Wright law is that public works cost more than private works. Now, in the Tuolumne County, I think the Wright system is excellent, for unless some huge corporation should construct that Modesto and Turlock dam it would never be constructed. It is better therefore to have a district corporation for such a purpose than a private one. My idea was that every acre of land had its just right to water in a proportionate share: Then the people would construct canals, and even if the water was not sufficient to irrigate all the land it is better that way than that a few men shall have it all. I want every man to have some. More than that, when one man irrigates his land he benefits all his neighbors. If you will take a cross section of a ditch and the country under it you will see that the water seeps away until it strikes the next ditch, thereby benefiting every man under the canal, whether he pays for water or not.

Mr. Vincent was asked if the disposition of the vested rights, or the usages growing out of the present system of canals that have taken water in Fresno County, is the chief practical obstacle to the formation of districts under the Wright law in and around Fresno; were the people here satisfied and did not want to experiment any further?

In reply, Mr. Vincent said:

That is about the fact, but the idea I had was this: In sections where there are no canals established the Wright system is the best, because every man under it will pay his proportion of expense from the beginning and receive all the benefit. In sections such as Fresno where the people have rights under the canals, I think a water district would be better than an irrigation district—that is, all the land should be formed into a water district and then the people should purchase the vested rights now existing. The principal object of the Wright laws now seems to be the construction of irrigation works. In Fresno, for instance, it would not be necessary to construct irrigation works, because we have a system already; but if we could purchase all the water rights it would be better. I was not able to get my bill signed by the governor after it passed the legislature of 1887.

My idea was that the water in a water district should belong pro rata to the land irrigated. The tendency of such a system would be to make water common property. The man now who is nearest the head of the ditch can get more water than he needs, and if he don't buy it he gets it in various other ways. There is, in the opinion of many, but one honest man on each canal, and he is the last man that gets water. This system has been thought wasteful, but in this particular region we do not find so much fault with waste, as we want water to seep and fill the land.

After the passage of the irrigation district law Mr. Wright immediately interested himself in the formation of the Turlock district, which was the first formed under the law. The agitation of the question among the Turlock people led to the formation of the Modesto district. No better example of the flexibility of the system could be offered than these two districts. They are under separate management, but have united to build a great dam on the Tuolumne River, each bearing its proportionate share of expenses and adjusting all interests in the dam on a fair and equitable basis.

The following engineering review of the works was obtained by the special agent from Mr. C. E. Grunsky, C. E., during his investigation of Californian irrigation in 1891:

The Turlock irrigation district embraces within its boundaries 176,100 acres of the east side San Joaquin Valley plains. The district lies principally in Stanislaus County, only a small portion of it extending into Merced County. Tuolumne River forms its northern boundary and the Merced River lies at its southern limit. Its soils may be briefly described as sandy loams of great depth, excellent quality, and well adapted for irrigation. The rainfall throughout the district averages about 10 inches. The district in its present nonirrigated condition is a vast wheat field. By careful tillage the soil has been forced to yield cereals enough to be barely remunerative. Where water has been raised from wells by mills or horse power an occasional acre of orchard or vineyard emphasizes its productiveness. The surface of the ground is smooth and its slope quite uniform. Distributary canals throughout the district will therefore be located in most cases on land lines running from north to south or from east to west. The rivers between which the district lies have their sources in the high Sierra Nevada. The Merced River flows through the celebrated Yosemite Valley; the Tuolumne through the Hitch Hitchy. The former at Merced Falls, where it breaks from the mountain and enters upon its course across the east side plain of the San Joaquin Valley, lies in a secondary valley, being flanked by broad bottom lands from which bluffs rise 40 to 100 feet and more to the general surface of the east side plain of the main valley. The foothills of the Sierra Nevada gradually retreat from the river and have occasional spurs which protrude to the bluff overlooking the bottom lands.

Similar to the Merced River is the Tuolumne, but the projecting spurs of the foothills hug it more closely and follow it far out into the main valley. At Lagrange, just above which settlement the river breaks forth from a rock-bound narrow gorge or cañon, the area of the mountain drainage basin of this river is 1,480 square miles.

The elevation of the river at that point is about 200 feet above the ocean and that of the highest lands in the district, at a point about 13 miles further west, is about the same. Tuolumne River is the natural source of supply for this district; and that it will afford ample water is evident by the following table of flow in second feet, prepared in the office of the State engineer in 1885:

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1878	......	......	......	......	......	......	......	......	....	....	65	65
1879	478	1,876	2,797	4,456	5,086	7,061	1,977	183	39	30	101	903
1880	409	625	832	7,141	10,371	14,675	7,618	1,233	134	56	35	1,095
1881	2,884	6,755	2,879	6,260	7,274	5,225	1,996	391	125	130	193	620
1882	620	573	2,164	3,543	7,461	8,046	2,745	574	225	873	570	327
1883	654	490	1,310	3,270	8,180	6,540	1,635	490	327	262	327	327
1884	410	490	6,540	7,360	7,360	8,180	6,540	1,635	327	245	......	......

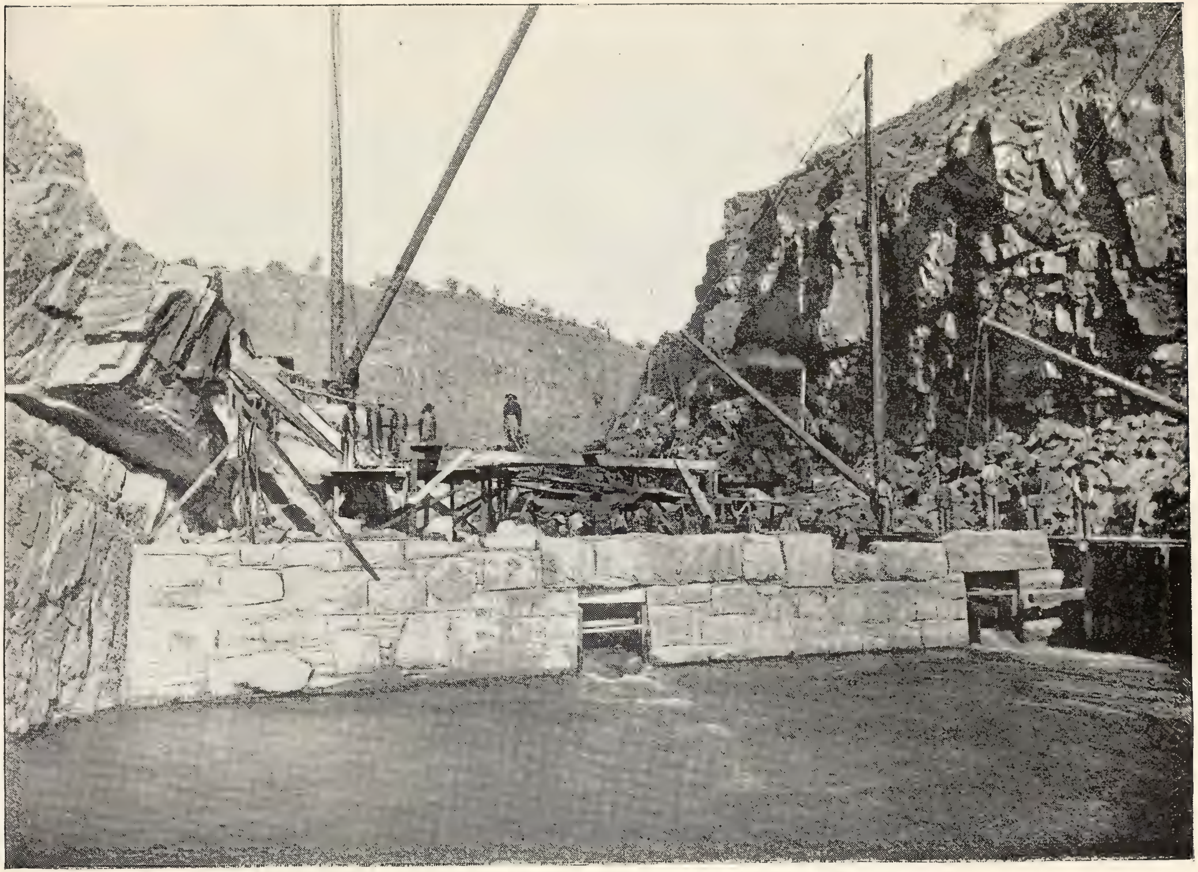
The capacity of the main canal as reported by the engineer of the district is 1,500 cubic feet per second. The duty of water (gross) expected of water in the district is 118 acres per second foot, on the basin of canal capacity. Although the lands to be irrigated are in part at least quite sandy, the duty of water is expected to be very low. A canal of somewhat smaller capacity would have been ample to supply the needs of the district; but a reduction in capacity would not have caused an equal reduction in cost of works, and as some one has said, the land owners in the district will be better satisfied with too much water than too little. Soon after its organization the district employed George Manuel as chief engineer, and on his estimate of probable cost the necessary issue of bonds was placed at $600,000. Little opposition to the scheme was manifested and the bonds were voted. After the necessary legal proceedings the laws under which the district was organized were decided to be constitutional by the supreme court of the State and the bond issue was then declared valid.

On specifications prepared by Engineer Manuel, the construction of works commenced in March, 1890, and was carried forward to the completion of about 18 miles of main canal excavation. Structures such as drops, flumes, and waste gates have not yet been constructed. The work inaugurated under Mr. Manuel's direction has been carried forward by his successor, E. H. Barton, the present district engineer. Original plans were improved upon as opportunity offered, and after long deliberations and many conferences with the Modesto district directors, which also looked to Tuolumne River as a source of supply, it was finally agreed by the board of directors of the two districts to construct a joint dam across the river at the mouth of its cañon, just above La Grange, on the "French Bar," immortalized by Bret Harte.

Plans from district engineers were called. It was agreed that the engineer whose plans were accepted should have charge of the construction. Subject to these terms the plans of Luther Wagoner were adopted, after having been pronounced the most acceptable by Col. G. H. Mendall, Engineer Corps, U. S. Army. Before the construction of the dam commenced Mr. Wagoner resigned as chief engineer of the Modesto district, and his plans for the dam are now being carried out under Mr. Barton's direction. The La Grange dam is constructed on the weir or overfall type. It will have a height of 105 feet, and extreme floods will sweep over its crest with a depth of about 16 feet. Its crest length will be 310 feet, the width of its crest 20 feet, the upstream face will be nearly vertical, the downstream face the shape of a pointed arch, each of the sides of which is formed of two contrasted curves. The overfalling water will drop 98 feet into a basin at the toe of the dam, 15 feet deep, formed by means of a secondary weir having a maximum height of 20 feet and placed across the river 200 feet below the main dam.

The width of the secondary weir will be 13 feet on top and its crest length will be 120 feet. The material is to be rubble masonry bedded in cement and concrete. About 32,000 cubic yards of masonry will be required. The contract for its construction has been let at $10.39 per cubic yard, but this price does not include cement, which is to be furnished by the districts. Its total cost will be about $400,000. The dam will be the highest of its type in the world.

The division of water for the Turlock Canal will be accomplished by means of a tunnel 560 feet long, 12 feet wide at the base, with vertical sides rising 5 feet to the spring of the arch, which will be semicircular with a radius of 6 feet. This diverting tunnel will have its head about 50 feet above the dam, and the flow of water through it will be controlled by means of the gates at its lower end, where the water in excess of that required for the canal, will be turned through waste gates back into the river. For a distance of over a mile below the head gate the canal winds along a steep slaty hillside, and the depth of water proposed is 10 feet. Its bed width is 20 feet, and its lower bank will be composed of dry laid rock retaining walls, having a thickness of 18 inches and inclosing a puddle core of earth 12 feet thick. At the lower



Turlock and Modesto Dam, Turlock and Modesto Irrigation District, California.

Looking up Tuolumne River from point just below dam in process of construction.

end of this hillside work in slate the canal crosses Snake Ravine. The crossing is effected by closing the ravine by means of a dam and turning the canal up the ravine a distance of nearly 1,000 feet, thence out through a cut 800 feet long, constructed principally by the hydraulic process.

Below this cut the canal waters will occupy old mining pits for a distance of over 2,000 feet, and will then flow through another cut in rock for 860 feet, into Dry Creek. The channel of this creek will be utilized for a mile and a quarter, being diverted by means of a flume, and thence westward, piercing three foothill spurs in tunnels, none of which require lining. Below the last tunnel a gulch is crossed above a dam having a maximum height of 40 feet, and the canal enters another cut 3,300 feet long. Peasley Creek will be crossed to a flume 20 feet wide with a water way 7 feet in depth. The canal below Peasley has dimensions adapted to a variety of material into which it is cut, being generally intended to carry water 7½ feet deep on a fall of 1 foot per mile. At the end of the main canal, which has a total length of about 18 miles, the water reaches the lands of the district and will be distributed by means of five laterals whose aggregate length will be 80 miles. They will carry water 5 feet in depth and will have bottom widths of 30 feet. Their fall is to be 2 feet per mile. In addition to these five principal branches distributaries to the extent of about 180 miles in aggregate length are to be constructed by the district. The sale of the original bond issue will not yield sufficient capital to complete the construction of the entire system of works, and an additional issue of about the same amount as originally voted is contemplated.

The plans for the important work on the dam have been well matured. It still remains an open question, however, whether the work would not be safer if artificial channels had been constructed past one or both of the ends of the structure, with long spill-ways dropping over the natural face of the cañon wall below the dam, rather than to permit the flood flow of the river to sweep over its downstream face. This flood at times exceeds 120,000 cubic feet per second. The enormous pressure belonging to such a flood flow is the basis of the not unfriendly criticism of engineers who have examined this work. The observations made in the summer of 1891 seem to fully justify the caution expressed in the suggestion. The importance and magnitude of this great dam also emphasizes the need of thorough supervision by municipal and State authority of all such structures, so that, in advance of work to be done, reasonable decisions may be reached as to the means and methods of security to be employed and completed.

The Modesto, which is associated with the Turlock in the construction of the division works on the Tuolumne, occupies a position between the Stanislaus River on the north and the Tuolumne River on the south similar to that of the Turlock district between the Tuolumne and the Merced. As originally organized the district embraced within its boundaries 108,000 acres. Based on the engineers' examinations and report, which were not made until an estimate of the cost of the works was required, it was decided to cut from the district boundaries about 30,000 acres of lands in the northeastern portion which had too great an elevation to permit a water supply for the entire district to be secured at the small expense hoped for.

The following extracts are from the report of C. E. Grunsky and refer to the district as originally established:

Two sources of water supply to be examined were Tuolumne River, which flows south of the district; Stanislaus River, which is north of it. Each of these rivers has a large volume of flow in the spring and early summer months. Both are comparatively small streams during the late summer and autumn months. The Stanislaus at Oakdale drains an area of 1,051 square miles; the Tuolumne at Roberts Ferry an area of 1,501 square miles. Taking the years from 1879 to 1884 inclusive, as a basis, the greatest average monthly flow of the Tuolumne River occurs in June, and for that period equaled 8,188 cubic feet per second; the smallest average monthly flow was in September, and equaled 196 cubic feet per second. From September there is a gradual increase of flow till the middle of June. During the same years the greatest average monthly flow of the Stanislaus River was in May, and amounted to 5,290 cubic feet of water per second. The smallest average monthly flows of the Stanislaus River occurred in September, and equaled 127 cubic feet per second, there being a gradual increase of flow from September to the latter part of May.

Based on the experience of irrigators in different parts of California, it is safe to estimate, as fully satisfying all demands of irrigators in this district (wherein sandy soils predominate and the average rainfall is about 9½ inches), that not to exceed 1 cubic foot of water per second will be required for each 160 acres of land from March to June, inclusive; not to exceed 1 cubic foot of water per second for each 400 acres will be required from July to September; not to exceed 1 cubic foot of water per second for each 640 acres from October to December, and not to exceed 1 cubic foot per second for each 1,280 acres during January and February. Water supplied at this rate would be sufficient to cover every acre of ground in the district 1½ feet deep from March to June, 9 inches deep in the next three months, and 2 feet 8 inches deep in the course of the whole year. To supply water at the maximum rate above indicated, the main canal must have a capacity of 675 cubic feet per second.

Stanislaus River may be relied upon to furnish this amount of water, though there will be occasional months (during the season when water is least in demand) when the full amount desired can not be obtained. For the six months from February to July inclusive its average flow is more than four times the amount noted above as desirable.

Tuolumne River ranks equally as high as a source of water supply for this district. It has a more extended watershed and a somewhat greater flow. But it is to be remembered in connection with this river that the requirements of Turlock irrigation district will be united to those of Modesto district. As the former has an area nearly twice as great as the latter, there should be available for both together about 2,000 cubic feet of water per second from March to June, 800 from July to September, 500 from October to December, and 250 in January and February. The river has an average flow adequate to meet this demand, but during the months of least demand for water there will be times when the river will afford less water than desirable (though by no means necessary for successful irrigation), particularly when some allowance has been made for riparian owners.

It was found that the highest land in the district is near its northeast corner, and that to accomplish its irrigation the actual elevation of water must be 30 feet higher than that of water at the cañon mouth of the Tuolumne River, about 200 miles above La Grange. The low-water plane about 2 miles above Knights Ferry, on the Stanislaus River, is barely higher than the highest ground of the district. The former of these points lies 21 miles in the district line from the northeast corner of the district; the latter is 11 miles distant. It was found impracticable to carry water on the riverside of the hills along the north bank of the Tuolumne and hold the same high enough to cover these high lands. Nor is it practicable to carry water to the south side of the Tuolumne and hold the same high enough. It is however feasible to direct water from the Tuolumne River into Dry Creek and thence by means of a small ditch to carry some of the diverted water to the highest lands of the district, while the main volume is permitted to flow in Dry Creek, a distance of 24 miles to the district lands. It is equally feasible to direct water from the Stanislaus River at a point about 2 miles above Knights Ferry at the lower end of Twomile Bar, and to carry it thence in a direct course to Buena Vista, thence across the gravel flat below Buena Vista to Wildcat Creek, in a flume across Wildcat Creek to Wildcat Ridge, along the face of this range of hills about one half mile, thence through the same in a short tunnel to Haskell Creek channel.

From Haskell Creek the water can be diverted sufficiently high to cross a divide about three-quarters of a mile south of the Lancaster place, whence the water would command nearly all of Dry Creek Valley. From that point the route of the main branch of canal to the district would be along the gentle sloping hillsides. Water brought into the district along this route would be high enough for all its irrigable lands.

At the lower end of the Twomile Bar, where the diversion of water from Stanislaus River must be made, there is an excellent site for a dam, and material for its construction is convenient and abundant. It will be necessary to raise the water surface at that point about 90 feet from extreme low water to the level of the water surface in the canal, in order to make it possible to keep the canal on the ground favorable for canal building. The probable cost for works for irrigating the whole district from Stanislaus River was estimated at $644,750 (not including right of way).

Referring to the question of irrigating the district by means of a canal from Tuolumne River, Mr. Grunsky says:

> It is less expensive to direct water from the Tuolumne River at or near the cañon mouth by means of a high dam than it will be to direct it at some point further up stream by means of a low dam and carry it in an expensive canal along the cañon wall. Dry Creek Valley at its head has an elevation of 130 feet greater than that of natural low water at the cañon mouth of the Tuolumne River. It will be necessary to raise water about 140 feet at that point to afford the necessary fall for a canal from the river to the creek.

This project would have involved the construction of three tunnels 2,800, 1,500, and 600 feet long, respectively, and the cost of the whole works, including distributaries throughout the district, was estimated at $1,118,000. After mature deliberation a bond issue sufficient to carry out the Stanislaus project was decided upon, and the bonds were voted to the extent of $800,000; but it was also decided that the interests of the land owners throughout the greater portion of the district could best be conserved by amending the district boundaries and excluding the high northeastern portion thereof. This was done, and the highest points in the district are now about 70 feet lower than at the time when engineer Grunsky made his surveys.

After additional surveys for the amended district were made by P. Y. Baker and F. G. Brooks it was finally decided to unite with the Turlock district, and to construct a joint diverting dam across Tuolumne River at the mouth of its cañon just above La Grange. The plans for this dam, devised by Luther Wagener, engineer for Modesto district, were accepted and its construction has been commenced. This has already been sufficiently described.

It is now proposed to construct the main canal along the foothills and on the flats upon the north side of Tuolumne River, a location which was not feasible before district boundaries were changed. The canal work will be very expensive near its head, but comparatively inexpensive after it has crossed the broken country within 5 miles of its head.

The lands of the district are for the most part sandy or sandy loams, but little of the heavier clayey soil near the base of the Sierra Nevada foothills being included within the district boundaries. The general land surface of the district is smooth; the slope is from east to west and ranges from a little less than 5 to about 10 feet per mile. Nearly all the land is devoted to the cultivation of cereals. The plains in their original condition were treeless. The lands of the district will be well adapted for intensive farming as soon as water is made available. The district has an area of 81,500 acres and extends from near the eastern edge of the San Joaquin Valley westward to the lowlands adjacent to the San Joaquin River.

These systems have been particularized somewhat at length, so that intending irrigators and others interested may obtain a reasonable idea of the methods required for the organization of district administration and the work of construction under the important irrigation and water code of California.

In the counties lying outside the great basin of the San Joaquin and Sacramento the seepage or the filling of the ground with water will play but a small part. The rivers are small and rapid in course, and the increase of the areas of irrigation by the water in sight must be accomplished by economical distribution. In many places in the Southern counties where irrigation has been practiced for a long series of years the soil has not been wet all the way down, and a cubic foot of water irrigates no more land to-day than when the ditches were first taken out. This condition has necessitated the adoption of pipe lines and cemented ditch systems. The great profit accruing from the culture of the citrus fruits, and the tropical abundance in which the more delicate vegetables are produced, have given the irrigators in the Southern counties ample means to pay for the expensive works rendered necessary. The costly works of the Turlock and Modesto irrigation districts, pro-rated to the acres, serve to make a lien per acre of but $9.81 in the Modesto, and $3.40 in the Turlock district. This is explainable by the fact that the two canals will irrigate more than 550,000 acres. While the five districts in San Bernardino County—Alexandro, Citrus, Belt, East Riverside, Grapeland, and Rialto—have been bonded at an average of $53.94 per acre for their water service, and but 58,787 acres are to be irrigated.

The Sweetwater dam, in San Diego County, is an example of the great energy. skill, and money that have been put into the development of a water supply. This work has been previously described.

The Bear Valley system, a short history of which was given in the Progress Report of 1890, is here again described because of the more accurate data obtained. The work now constructed and projected will eventually bring about 450,000 acres under intense cultivation. The credit of projecting this vast work belongs to Mr. Frank E. Brown, C. E., of Redlands, and the skill and daring with which his designs have been executed have developed the highest type of systematic irrigation on this continent. It is greatly to be regretted that the limited means and time at command prevent the production of a relief profile map of the catchment and irrigated areas involved. It will be seen that the Bear Valley reservoir is only a part of the great plan which Mr. Brown is carrying out. The bold structure at that point as at present standing is, however, worthy of particular and especial mention because of the fierce criticism aroused by its projection and subsequent construction.

The office of Irrigation Inquiry has made a special examination of this work. The structural character of the cross section of this dam has often been severely condemned, and while its duplication could not be recommended, the principle involved by it—that of the upstream arch dam for the formation of reservoirs on sites where the basin narrows into a rock bound gorge, is to be credited with great resisting power. The character of the abutments must however be carefully examined and tested, as the slightest fault at the point where the dam keys into the natural formation may prove fatal. In the Bear Valley structure the natural advantages for a work of this character can hardly be improved upon. At the point where the present dam is located the basin of the Bear Valley narrows until the cañon is almost closed, and the rocky sides of the mountain spurs descend precipitously. A bird's-eye view of the mouth of this reservoir would present an appearance like that of a bladder with a short section of the neck attached turning back on itself. At the turn of this outlet, with its arch force straight into the confined water, is placed the dam. The spillway is entirely separated from the dam, and is blasted out of a spur of live rock into which the dam is keyed. Owing to the peculiar nature of the gorge, unless the precipitation upon the catchment area should become too heavy for the spillway of 24 feet wide and 28 feet deep, the dam could never be subjected to an unusual pressure. This dam will soon complete its eighth year, and in the opinion of the engineer whose reputation is involved can be disturbed by nothing short of an earthquake. Whether a stronger constructed cross section would withstand such a force need not be discussed. The new dam will however be subject to no censure for want of resistance to either gravity or static inertia, as the dimensions given will show. The same bold intellect that created the Bear Valley dam is at work on the no less notable project of a system of reservoirs, including those of the White Water and San Jacinto. The first will make it possible to practically distribute water that falls on one side of the San Bernardino Range upon the other slope. The areas to which this water will be distributed lie in two counties, San Bernardino and San Diego; and those acquainted with the region will be struck at once with the simplicity of the design and the vast conception of engineering forces brought into play. The Bear Valley Company, while developing the greatest system of hydraulic works in connection with American irrigation, is also to be commended for equal foresight in its readiness to conform to the expressed wishes of the people and laws of the State. It was probably the first corporation in California to encourage the formation of the irrigation districts within the area commanded by its pipe lines and ditches, and the same broad conceptions that have marked its engineering department are followed in its dealings with the users of water.

The Bear Valley Land and Water Company was organized in the summer of 1883, and a force of men immediately put to work. About 250 cubic yards of masonry were placed in the foundations of the dam that fall before the snow and ice of winter compelled an abandonment of the work for the season. Early in the spring of 1884 the work was resumed and pushed vigorously throughout the summer and fall, the dam being completed as it now stands in November of that year.

The location is in the San Bernardino Mountains, sbout 18 miles air line northeast of Redlands, and 6,400 feet above sea level. The structure is of granite rubble in Portland cement, mortar resting on a foundation of solid granite in place. It is curved in plan, having a radius of 335 feet measured to the lower face, which is vertical. It is 64 feet high from the bed rock to the top of the coping and has a length of 250 feet on the crest. The back or side next the water batters from a thickness at the top of 3 feet 2 inches to a thickness of 8 feet 6 inches at a depth of 48 feet; at this point an offset on either side increases the thickness to 12 feet, and from here down a batter on either side increases the thickness to 20 feet at the bottom.

This dam backs the water 5 miles up the valley, and covers 1,859 acres at an average depth of 14¼ feet. The cost of the dam was about $120,000; this cost being greatly augmented by the fact that the cement and supplies had to be hauled by wagon a distance of 100 miles over a mountainous road. The catchment basin has an area of about 77 square miles, and the average rainfall for the last seven years has been about 53 inches per annum.

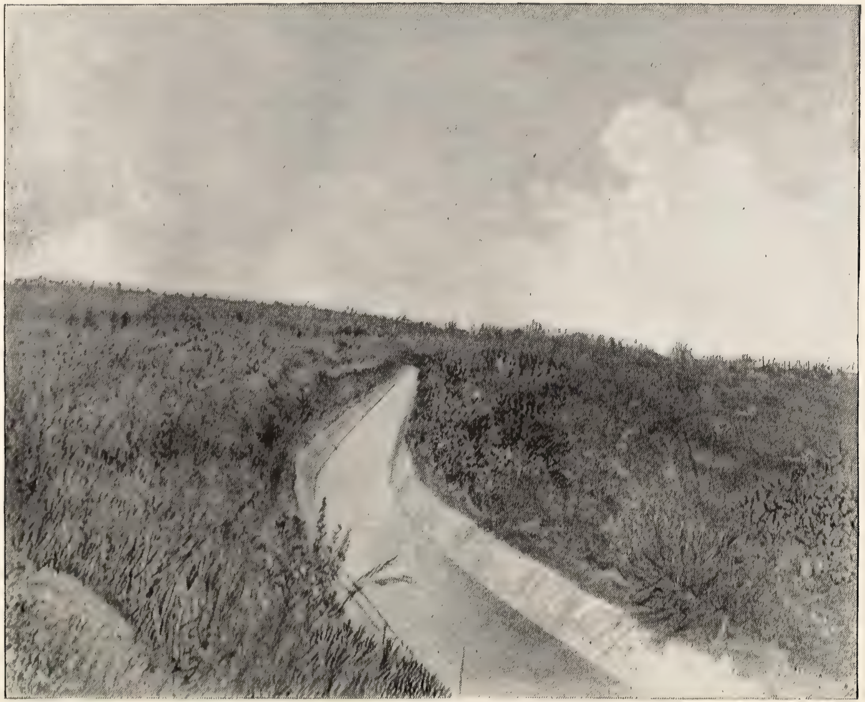
In the year 1890, the Bear Valley and Alessandro Development Company was formed, owning 21,000 acres of land in the Alessandro Valley and a controlling interest in the Bear Valley Land and Water Company. Later these two companies were consolidated and reorganized as the Bear Valley Irrigation Company. The latter company now owns all the property, rights, and franchises formerly held by the other two, and in addition has acquired by purchase various other reservoir sites and water rights, including the right to the entire flow of Whitewater River, Mission Creek, Snow Creek, and the Santa Ana River, and the surplus winter waters of Mill Creek. Heretofore the irrigating power of all these streams has been limited to the extent of their capacity for supplying water by their natural flow in the dry summer months, and still further reduced by the wasteful methods formerly in vogue, of conveying the water in open ditches, running sometimes for miles through the loose sand and bowlders of the river washes, and losing a very large percentage of their waters by seepage and evaporation.

It is the design of this corporation to not only greatly increase the irrigating power of these streams by constructing better and more permanent forms of conduits, but also to augment the summer flow by running tunnels to bed rock from the sandy beds of the stream, thus intercepting the underflow and conveying it to the surface, also by constructing great reservoirs to impound the surplus winter water. To this end many miles of the main and lateral canals have been paved and cemented; over 120 miles of steel, vitrified clay, and cement pipes ranging in bore from 30 inches to 6 inches have been laid; over 2,000 feet of tunnel has been run in the bed of the Santa Ana River, and as many more feet bored through the rocks; plans have been made and work begun on a new and higher dam at Bear Valley which will multiply the present storage capacity many fold; and various other reservoir sites have been purchased. Among the latter is a reservoir site on the Santa Ana River at an elevation of 4,500 feet, which will impound about 12 000 acre feet of water; another in the San Jacinto Valley, which will hold about 120,000 acre feet; and still another in the Potrero Valley, which will contain about 30,000 acre feet. Work is now in progress on all these various sites excepting the Potrero, which has not yet been started. These reservoirs will be pushed to completion in the order in which it is expected that the demand for irrigating water will occur, holding the stored water several years ahead of the probable demand.

First in order is the new Bear Valley dam, the foundation of which is now being prepared immediately below the present dam. Plans had been prepared to build this dam to a height of 129 feet from bed rock to the water line, which will raise the level of the lake 67 feet above present high water, backing the water 12 miles up the valley, and increasing the storage capacity to 461,650 acre feet. Owing to changed conditions brought about by acquiring new reservoir sites at lower levels which will answer the purpose of conserving a larger proportion of the surplus winter water at a less expense, and reduce the length and cost of canals necessary for conveying the water, it has been decided to stop this dam at a height of 89 feet from bed rock for an indefinite period. This will raise the level of the present lake 27 feet, backing the water a distance of 7 miles, and submerging 3,300 acres to an average depth of 29 feet, thus storing 95,700 acre feet. This, with the 12,000 acre feet to be impounded by the auxiliary dam in the Santa Ana Cañon, will in all probability be an ample supply for all available lands lying between the level of the head gates of the canals in the Santa Ana Cañon and the level of the great storage reservoir in the San Jacinto Valley.

Next comes the dam in the Santa Ana Cañon; this will be of stone, 175 feet high and about 300 feet long. A tunnel, 750 feet long, through solid granite and large enough to carry the ordinary flow of the river, is nearly completed for the purpose of acting as an outlet for this reservoir, and for diverting the stream while the dam is being constructed. As soon as the tunnel is ready, active work will be commenced on the dam itself.

The reservoir site in the San Jacinto Valley is a depression in the midst of a rich alluvial plain, where the San Jacinto River broadens out, forming at high water a considerable lake or laguna, as such bodies



Modern "Cement" Ditch, Bear Valley System. Redlands, California.

of water are locally called. The outlet to this lake is a narrow opening less than 1,[illegible]00 feet in width, passing between two low ranges of mountains, and it is at this point that the dam will be constructed. A large number of borings have been taken at the proposed site of the structure showing the substrata to consist of alternating layers of clay, sand, and gravel to a depth of 60 feet from the surface. This dam will submerge 9,300 acres to an average depth of 12 feet, thus storing 116,000 acre feet of water. Artesian wells flowing water under a considerable pressure have been found in the region of this lake, and although they will not be relied upon as a means of filling the reservoir, yet it is expected that they will go very far toward compensating for the inevitable loss by seepage and evaporation.

This great reservoir is to be filled during the flush winter and spring months, partly by the San Jacinto River and partly by the Whitewater, a mountain stream, which will be diverted at a point about 30 miles distant and conveyed to the reservoir partly in pipes and partly in open paved and cemented canal. These works will have carrying capacity of 15,000 miner's inches, or very nearly two-thirds of that of the new Croton Aqueduct. Later another aqueduct turning the surplus waters of the Santa Ana River and Mill Creek into the same reservoir will be constructed. The Potrero Reservoir proposed is not yet begun, but it is probable that a stone dam impounding about 30,000 acre feet will be constructed at that point.

Originally in the distribution of water, the Bear Valley Land and Water Company adopted the method of issuing certificates per acre entitling the holder to the right of using one-seventh of a miner's inch of water perpetually; these certificates were transferable, and were supposed to represent water sufficient to irrigate one acre of land. Of these, 7,200 were issued to the stockholders in lieu of dividends; two certificates to each share of stock. They are liable for an annual assessment or tax for the purpose of maintaining, repairing, or reconstructing the canals through which the water flows.

The present Bear Valley Irrigation Company has adopted a somewhat different method of distribution, having issued 100,000 certificates entitled "Class B" acre water-right certificates. Each certificate entitles the holder to 1 acre foot or 43,560 cubic feet of water each year, and the holder of each certificate pays to the company an annual rental of $2.78. Under these certificates and within certain prescribed maximum limits the owner may accumulate the water so as to use more in the dry summer season and less in the winter. Of these acre water-right certificates 51,000 have been sold to the Alessandro irrigation district; 16,000 sold and 5,000 more contracted to the Perris district, and 8,000 have been contracted for by the Elsinore district. The water is conveyed by the Bear Valley Company to some point agreed upon, generally within the irrigation district, and there taken charge of by the district authorities.

The form of conduits vary according to conditions, nature of country traversed, and character of service required. For the country about Redlands, Crafton, Highlands, and North San Bernardino, a region of great beauty and fertility, having a considerable population, open canals of a trapezoidal cross section, paved and cemented on the bottom and sides, are used, the paving being of granite bowlders from 6 to 10 inches in diameter, and the mortar composed of Portland cement and sand, costing when laid in place about 13 cents per square foot of surface covered. Where possible, these canals follow the contour of the country, on grades varying according to the capacity of the canal, so as to give the water the velocity of from 2 to 5 feet per second, it being found by experience that with velocities much below 2 feet per second the channel will become obstructed with aquatic vegetable growths, and with velocities greater than 5 feet per second the erosion will be so great as to seriously injure the cemented bottom of the channel.

Pipes and wooden flumes are used where necessary when crossing depressions. A wooden flume in the Santa Ana Cañon has been replaced with a wooden pipe 48 inches in diameter inside. This pipe is 2,000 feet long, and is built up in place with staves of California redwood and banded with hoops of round iron five-eigths and three-fourths inches in diameter. The hoops are spaced according to the pressure to which the pipe is subjected; the lowest point in the depression being about 45 feet below the hydraulic grade line, the hoops at this point being three-fourths inch round iron, spaced 7 inches apart. The top of the entry end of this pipe is level with the bottom of the delivery end, so that no matter how little water is running, the pipe will always be full. The entry end of the pipe starts from the bottom of the vertical penstock or forebay, which gives the water the necessary head for forcing it through the pipe. The present capacity of the pipe is about 4,000 miner's inches. When, in future years, it becomes necessary to force a larger amount through the pipe, the water will be delivered in the forebay at a higher level, thus giving the pipe the additional head required. The staves of the pipe are 2¾ inches in thickness, being taken out of 3 by 6 inch timber, and machine dressed to the true curve inside and out. This pipe has been in use for several months and so far has proven entirely satisfactory. It rests on redwood sleepers placed transversely 10 feet apart and about 1 foot above the surface of the ground. The entire cost, exclusive of grading, was $3.63 per foot.

Another notable pipe is the one leading the water from Mill Creek to the Alessandro irrigation district. This pipe is made of riveted steel and is 10 miles long. The first 2 miles is 28 inches in diameter and the balance is 24. The sheets vary in thickness from No. 14 to No. 0 by the Birmingham wire gauge, the thickness increasing according to the pressure to which the pipe is subjected. The lowest depression on this pipe line is 400 feet below the hydraulic grade line. Blow-off gates are provided at all depressions, and automatic air valves at all summits. The capacity of this pipe is about 1,000 miner's inches. The total cost of the line complete, including cost of 4,000 feet of tunnel, was $210,462. There is also a few miles of cement pipe ranging in size from 6 to 30 inches. For the most part they are composed of Portland cement and sand in the proportion of 1 part of the former to 4 of the latter. They vary in thickness of shell from 1 to 2½ inches, according to the size. They are made by a hand machne in 2-foot lengths and are seasoned in the air twelve days before laying, being kept sprinkled with water all the time.

The joints are put together in the trenches with strong cement mortar, thus forming a continuous pipe. This kind of pipe, though largely used in the past, has not proved entirely satisfactory. A better class of pipe is the ordinary salt glazed vitrified clay sewer pipe, and of this kind the company have already laid over 32 miles in sizes ranging from 6-inch up to 24-inch. By doing a careful job of laying, this pipe can be placed under heads of 20 to 30 feet safely. In cases where it is necessary to subject the pipes to greater pressure, as for instance, where orchards are planted on rolling land or hillsides steel or iron pipes are used. In such cases, if the hills are very steep, they are terraced; if the slope is more moderate the trees are planted around the hills on contours having a fall of 2 or 3 inches from tree to tree. At irrigating times furrows having a uniform fall are run around the hillsides above the rows of trees, and these furrows are supplied with water from hydrants tapped into the main pressure pipes which follow the higher ridges of land. All canals, conduits, and pipe lines are under the immediate care of division superintendents, called by the Spanish name, zanjeros.

A person wishing to irrigate his land gives notice to the proper zanjero three days in advance, stating the quantity he requires, and the water is delivered to him through a pipe and hydrant, and is measured over a weir at the highest point of his land. From here it is usually conveyed in small wooden flumes or cemented brick ditches, and delivered to the heads of the irrigating furrows through holes in the sides of the flume or brick ditch.

The same parties also own the surplus carrying capacity of the North and South Fork canals, taken out of the Santa Ana River at its points of emergence from the cañon. The North Fork will be extended westward to cover about 10,000 acres in the Muscupiake Ranche, near the city of San Bernardino; and the South Fork will furnish water for the irrigation of the Lagonia and Sunnyside settlements in the eastern portion of the San Bernardino Valley. One result of the course followed by the management is the gradual replacing or abandonment of the old ditches made by the Mexican or early American settler. This change may be regretted by the lover of the picturesque, for their course is marked by the verdure of trees and indicated by luxuriant undergrowth, but they are exceedingly wasteful, often failing in supply when most needed. The new policy guarantees each user the amount he claims from the older ditch. He claims but often fails to receive.

Mr. L. M. Holt, the editor of the Orange Belt Redlands, Cal., is a very close observer of the progress of irrigation in California. He has been identified with the growth of the system almost from its birth, and his opinions are of great value. The following interview giving the history and application of irrigation in the southern section with the special agent will be found valuable in connection with the district system. The application of the principle of the Wright law as discussed by Mr. Holt opens large avenues for successful investment and great opportunities for popular development of homes. He says:

The old style or old school of irrigation practiced in the coast valleys in this State is nearly exhausted. The original bringing out of water here was in crude open ditches when it could be brought out of the running streams and put on the lands within the river valleys, when it could be gotten out the cheapest and was not applied to the mesas at all. It was not until 1872 at Riverside that any attempt was made to irrigate the mesa lands.

In 1875, the original Pomona Canal was organized on the basis of the ownership of the water by the users of it, a share of stock to go with each acre of land. I was secretary of that colony. That was followed by the Redlands Company, the Etiwanda Company and the San Antonio Canal to irrigate Ontario. In 1884, the Riverside people pulled out to fight the old company, bought them out and organized on the same plan. In 1880, there was only considered to be enough water to irrigate 10,000 acres of land in San Bernardino County. In 1890, with improved methods for the storage and development of water, the area has increased until it is now estimated that 140,000 acres can be irrigated. Up to 1880, the open ditch was the only system, and from that until 1890 there were other methods. We commenced cementing the canals to save seepage, and adopted flumes and pipe lines; and instead of distributing the water in ditches in southern California it is done now almost entirely by cemented, vitrified, wooden, or steel pipes. Redlands was the first to take up the pipe system, then came Ontario. When we got all of the streams utilized there came the proposition to use more water. It could only be done in three ways, by artesian wells, tapping the underflow, or by storage. Ontario was the first to adopt the artesian system. The Gage system adjoining old Riverside was the next one.

They depend entirely upon artesian water. These are the only two places that have adopted artesian systems to utilize water on the mesas, that is, taking the water from the moist lands out on the mesas. The water here on the mesa is found only in the cienagas. In 1882, Frank E. Brown, of Redlands, had to have some water for his settlement, and I suggested to him to use the underflow of the Santa Ana River, and that was the first time the utilization of the underflow was broached. I knew there was an underflow, and I was satisfied that there was a bed rock under the stream and that this bed rock was holding the artesian flow below; and if the bed rock was not too deep you could develop this lost water of the rivers. Another proposition was that the further up the stream you went the more water you found in a given area. He adopted the plan and is now gradually completing his tunnel and getting a considerable supply. The next year I suggested the same thing to George Chaffey for his canal, and took him up to Brown's tunnel, which had 40 inches of water in it developed from a bowlder formation in which you would not think there was any water. That tunnel is now up to bed rock, and they are drifting out from the upper end to let the water in from above.

Q. Now, your acquaintance with this mountain region is very intimate, and I should like to know your idea as to the possibility of extending or developing its underflow. As progress goes on, there must be unquestionably many small settlements in the valleys here that would get no water from the surface that might be reclaimed from phreatic sources. What is your view?

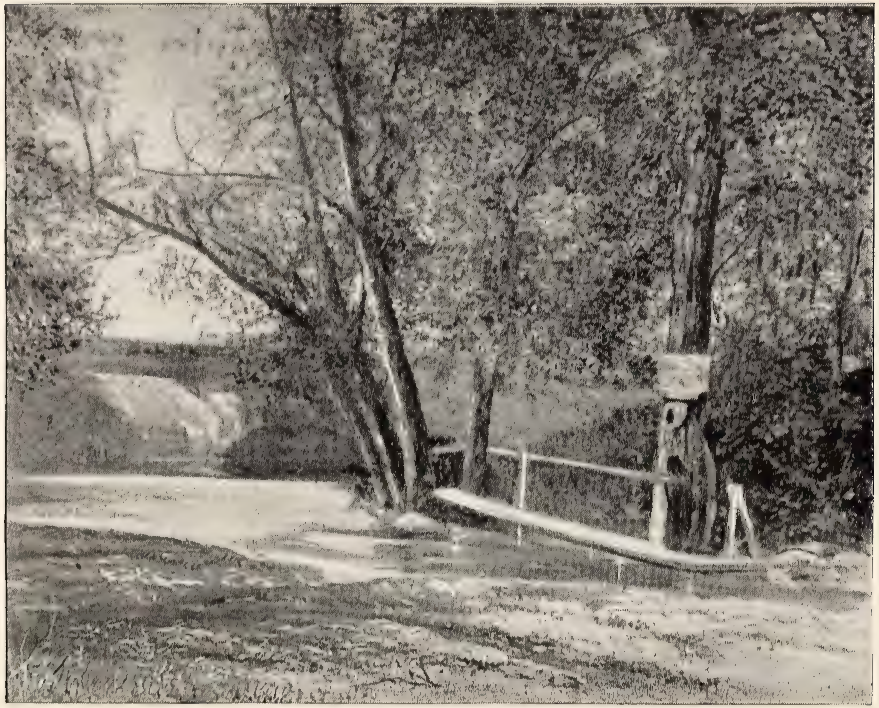
Mr. HOLT. There is no question that a tunnel up into any of the mountain cañons will develop water; but the cost of it is so great that it will not pay to do much of that work so long as you can get a good supply from a storage system. In 1883, we began the adoption, and in 1884 the first reservoir was completed in Bear Valley. It was an experiment for six years. People did not have confidence in it; and under the laws of the State, as we had them at that time, there was no practical way of placing water on the land; and if it had not been for the passage of the Wright law the storage system could not have been adopted with any degree of success, and the Bear Valley enterprise would have been a practical failure. That company has authorized the issue of what they call "acre water-right certificates," each water right calls for an acre-foot of water during the season, or for a supply sufficient for an acre of land. In this way the water is wholesaled to the district.

In the way water is used in California an acre-foot of water will supply an inch to 8 acres during the summer months and will give all the water that is needed for the balance of the year on the basis that about one-half of the entire supply is called for in June, July, and August, and only one-fourth during the months from November to April, and the other one-fourth during the other three months. On these lines an acre-foot of water will give 1 inch to 8 acres, and all acre water rights are on that basis. They sell acre water rights to a district. The district can buy as many as they want. They can buy 1 inch to 8 acres or 1 to 4, just as they please, or often more. It was thus that the organization of districts made it possible to make this wholesale storage and commerce possible. But in the management of distribution the reservoir people have no existence; the district takes what water it wants and distributes it to satisfy itself. The Bear Valley, having secured its legal rights of appropriation and storage, is necessarily in harmonious relations with water districts. There is no likelihood of an attack on the company. The people of the small districts look upon it as their friend; that is, they can get water cheaper that way than to try to store it themselves. Under the system, then, it is calculated that they will irrigate from 400,000 to 500,000 acres of land in San Bernardino and San Diego counties.

Q. The organization of the Bear Valley and other enterprises, with accompanying colony methods of land settlement and cultivation under them, appears to me to have carried the irrigation areas onto higher altitudes; that is, it comes up into these intramountain valleys and affords, as I see it, a very extended possibility of reclamation. Can a system similar to the Bear Valley be applied to the Antelope Valley, for example?

Mr. HOLT. The trouble there is the rainfall areas. The rainfall in the mountains is about five times what is in the valleys; and therefore 100,000 acres of valley land will not get more moisture than 20,000 acres of mountain land. The average fall in Bear Valley has been 60 inches. Last winter there were 31 inches of rainfall in forty-eight hours, and the water raised in the dam 2 feet in twenty-four hours over that immense lake, notwithstanding the fact that at the outlet, 24 feet wide and 28 feet deep, the water was running out all the time. The water supply in this section for the future must be gotten almost entirely by storage reservoirs in the mountains. A storage reservoir within a valley watershed is of no account in this country. One reason of that is the smaller loss in the mountains. There is less evaporation and larger rainfall, and you can save a large percentage of it.

Q. Taking generally the situation of irrigation as a matter of peace and order on one side, of business security for the investor and user on the other, and also of future



" Zanja," or Old Style Open Ditch. San Bernardino County, California.

development, what has been the effect of the passage of the Wright laws, taking first Southern California and then the whole State, as you know it?

Mr. HOLT. It has had the tendency to settle all disputed water claims and to develop our water resources very rapidly. We have at the present time (June, 1891) about thirty districts in the State. There have been a few others that have tried to organize or organized illegally, but there are about thirty districts in all. They have voted about $13,000,000 in bonds. There have been about $4,000,000 of these bonds sold either for cash or traded for water-right certificates, and in the history of the State there has never been anything like the development of the last four years. The supreme court has decided the system constitutional and stood by the districts in every way. The financial public is beginning to appreciate the value of such securities, and money can readily be had to carry on the work. Mr. Adolph Wood, of the Arrowhead Reservoir Company, told me that if it had not been for the passage of the Wright laws his company would never have thought of putting its money into a reservoir system.

Q. Has the effect of the district system as applied to water and water-works ownership and the settlement of legal questions been such as to content capital with the profitable repayment of its money invested, and to get rid of the idea of its controlling the works and the water for all time?

Mr. HOLT. Yes, sir; the old feeling of antagonism has vanished to a certain extent. The districts recognize the fact that it is impossible for the people to go into large propositions of reservoir storage, because one system may be large enough to supply several districts; and if a district can have a certain amount of water delivered properly they can afford to pay a certain amount of money instead of keeping up the existence of a reservoir large enough to furnish other districts. Then, information has tended to remove all the former quarrels, disturbances, and disputes that existed between the corporation and the users of water. This is one of the principal effects. It is a recognized fact that these districts can exercise the right of eminent domain and condemn water if it can not be obtained otherwise; and after a district is once organized the canal companies do not stand out to litigate, but take any good price. The bonds are considered sound. The only question with the companies now is how many they can get. Riverside is practically a community effort, in the sense of that term, because the stock is centered among the owners of the land; and the same is true of Etiwanda; but at Etiwanda they are discussing the proposition of putting the community stock into an irrigation district. At Etiwanda there are some conflicting interests that can better be settled by a district than by the owners of community stock. The original projectors had a contract by which they had the right to develop water for fifteen years, and that contract is about to expire. They had the right to measure the water on the 15th day of August and call for more stock on account of any water developed; and they are rather anxious to crowd that proposition by taking the measurements in wet years.

Q. In watching the operations upon the western half of the arid region have you ever thought of the possibility of extending the district system over the public lands therein by the coöperation of the State, Territory, and United States?

Mr. HOLT. I have thought of that and it has occurred to me as being about the only way that the question could be practically reached. Some modification of our State law would perhaps have to be made in order to make the system fit well with somewhat different conditions.

The proposed Arrowhead reservoir system in San Bernardino is another notable water-storage proposition. It is the outgrowth of the peculiar situation of southern California, and has received its direct stimulus, according to the engineer's statement, from the adoption of the Wright laws. The watershed lies north of the San Bernardino Mountains, embraces about 75,000 acres, includes Deep Creek and the East and West forks of the Mohave River. There are to be four reservoirs linked together and above one another, so that if one breaks its flood will be emptied into the others. The highest reservoir is located in what is known as Little Bear Valley. That basin empties into the Deep Creek Reservoir. The Little Bear Valley is connected with the Deep Creek watershed by a canal which starts at the mouth of Holcomb Valley, and, winding around, intercepts the tributaries of Deep Creek. This canal is 17 miles long, and its water is conveyed in a northeast direction into Grass Valley. From there the canal is continued southwesterly into Houston Valley, and from thence the water is conducted into Seeleys Valley, at which point the water is taken into a tunnel about a mile through the mountains that empties into Cañon Diablo. The Arrowhead watershed begins on the divide between Bear Valley and Little Bear Valley. There is an estimated annual rainfall of about 60 inches, and besides this there are large cienegas and enormous springs emptying into the catchment basins. The altitude of the catchment basins varies from 4,800 to 8,300 feet above sea level. The irrigable area begins at the mouth of Cañon Diablo, where the mouth debouches into the valley lands. Five engineering parties were in the field in July, 1891, and a road 17 miles long had been constructed into the mountains. It is claimed that all the country lying in the direction of the Riverside settlement and between them and the Arrowhead may be irrigated from the reservoirs proposed. This company has been organized for the special purpose of selling water to irrigation districts. And this determination indicates an understanding of the sagacious policy first pursued in southern California by the Bear Valley Company and its astute directory.

The vital question in the future of irrigation cultivation, so far as the fruit-growing sections of California south of the Tehacapi Range is concerned, is bound up in the matter of storage. No more profitable investment can be found there than the control of a good catchment area, with appropriate storage sites for holding and conserving the precipitation thereon. It is not difficult, then, to perceive the force of the testimony given the office of irrigation inquiry, to the effect that such investments are made more secure as well as more profitable by reason of the adoption and enforcement of the laws providing for the organization of irrigation districts, for the distribution and management of water. The Bear Valley managers were emphatic in testifying to the special agent that they could not successfully carry on their great enterprises by dealing directly with individual users of water. Hence they have, as business men, done all that is possible to facilitate the organization of districts to be supplied from their storage system, recently increased, it is reported, by appropriations to cover 200,000 additional cubic inches of water. The individual irrigator is too often inclined to litigation. He is always complaining. With the district authorities the storage company claim to be able to deal on the plane of public interest. This, at least, is their testimony. In its degree it is a remarkable tribute to the value of the Wright laws. But it presents another feature which operators in and organizers of storage works will have to take into consideration; that is, the fact that the district system is the logical outcome of the social economic necessity which, wherever irrigation is the essential need of cultivation, must make it tend rapidly to the policy of public control, ownership, and management of water and works needed in any community for the maintenance of agricultural security. The Wright district system in California provides for the public control of storage areas and works as much as it does for distribution and management. This is logically embraced within the laws, but as a practical fact it has so far escaped its operations. As the land laws of the United States permit the appropriation of water for beneficial use on the public domain, the majority of storage areas and sites are being taken up. In California a still larger number of appropriations were under the control of Spanish and Mexican land grants. But the power to direct the disposition and use of water for beneficial purposes remains with the State. It has been exercised most wisely in the matter of irrigation district organization. The question is sure arise whether or not the State will exercise its powers of sovereignty and eminent domain at some not distant day, so as to transfer by law, amicable purchase, or legal condemnation, the great storage reservoir systems that now exist or that will be made ready for operation. It is quite certain if it is ever done it will be on grounds of the highest public needs and upon full compensation for all investments. Such possible action is in the logic of the situation. In the meanwhile there are large returns awaiting enterprise in this direction and a certain continuance of profit in the bond income that would follow a transfer to State or district.

During the next two years in California there will be added to the area reclaimed in this State, by works now in process of construction, more than 2,500,000 acres of land. This great advance has been the result, primarily, of the passage of the Wright laws. The opposition, so bitterly pressed, to the operation of this statute has had one valuable consequence. The bankers and moneyed interests of the State determined last summer with the assistance of J. W. Nance, president of the State association of irrigation districts, to make a close examination into the physical, engineering, and business problems and conditions of the districts, together with a statement of the legal status of each. Messrs. Wilson & Wilson have been retained to report on the legal problems involved, and Mr. Wm. Ham. Hall, ex-State engineer of California, has charge of the economic and business side of the investigation. The work, so far as completed, has been ably done. Only three districts, however, have been examined and reported on, *i. e.*, the Central, the Perris, and Alessandro irrigation districts. These reports have been made respectively on July 25, August 15, and October 1, 1891.

The matters examined and reported on include the physical data of each district, its adaptability to and necessity of irrigation, water supply, duty and delivery, works, cost, district valuation, and bonded indebtedness, present and future financial condition and outlook, irrigation bonds, rights of way, contract rates, cost of irrigation, character and condition of the work and its probable effect, together with a report on all litigation, and the tenor of local sentiment for or against the works and projects of each district. All these points are carefully and ably considered. In the report on the Central district, discussing the necessity of irrigation therein, Mr. Hall makes the following interesting comparison:

> The valley of the Po, in Italy—the classic land of irrigation—although it is most copiously watered by nature's methods and processes, is, also, artificially irrigated more freely and fully than it is proposed to irrigate in any district of this comparatively very dry California. The Italian valley, in form and in size, is almost the counterpart of our Sacramento. It receives on the average, according to special locality, from 22 to 35 inches of precipitation annually, as against local annual averages of 14 to 21 in our Sacramento Valley. And yet in that special region in the valley of the Po, embracing a great extent of country, where the rainfall averages about 30 inches per year, and is much better distributed through the months than with us, irrigation is practiced to that extent and intensity that the cubic foot of water per second serves only 60 to 70 acres of land, while the same volume of flow is expected in California to meet all demands on at least two or three times as great an acreage. But that Italian irrigation serves to support 200 or 300 people per square mile; and though rainfall is so copious and well distributed, the artificial application of water is just as necessary to the support of that population as it would be to the support of 20 to 30 people, even, to the square mile on one of our driest and least productive plains. Without irrigation, about the same proportion of both populations would have to emigrate or die.

Discussing the supply and duty of water, the report proceeds:

> There is an abundance of water to spare in the Sacramento River to supply the Central irrigation district canal to the utmost capacity now projected, namely, something less than 750 cubic feet per second.

> There are no other canals diverting from this source, except some insignificantly small ditches. There are no other works in course of construction, or claims to water likely to interfere with that of Central irrigation district.

This supply, at the rate of 1 cubic foot for 150 acres is amply sufficient for the class of cultivation likely to be practiced in the district. The area of the district is 156,550 acres, which, minus 10,000 taken up with public and private rights of way, will afford 146,550 acres that may be actually cultivated every year. The value of land with and without irrigation in the Central district is repored:

> It is generally considered that wheat-raising, as a business on fair to best lands, when conducted systematically in large tracts in the region of this district, justifies land values of $30 to $50 per acre. If we were to judge these land values from the rates per acre thus far paid for right of way for the main canal of this district, even allowing largely for the element of damages to the other acres of the tracts crossed, by reason of the presence of the canal, we would be led to fix upon valuation materially in excess of the above.
>
> In my opinion, the farming lands alone in this district (rated as a savings bank would rate property in California, in considering it as security for a loan), are worth on the average $30 per acre, or, say, $4,500,000. It is not necessary for the purposes of this report to try to make any estimate of, or express any opinion on present values of other district property.
>
> If irrigation is introduced and well administered, and the farmers profit by it as fully as they should, and demonstrate their ability to, and intention of so profiting, within five years after water distribution commences in this district, its farming lands, by that time being extensively planted to fruit and sown in alfalfa, should, in the light of abundant experience in this State, be worth, as mortgage securities, $9,000,000. Be it remembered that every acre of the district would have a water right attached to it, and that the annual cost of irrigation would be the expense of administration, maintenance, and interest on bonded debt; and that each acre would have its cash value reduced, by reason of that debt to the extent of its share of it.
>
> The total assessed valuation of property in the district is now $2,720,770. In my opinion it is altogether within limits to assume that as soon as irrigation is brought to command the lands of this district, its taxable property may be valued, as such valuations are here made for tax assessment, at $3,000,000; and that if irrigation is extended with any reasonable degree of progression, as compared to rates of advance made under similar conditions elsewhere in California, an additional $250,000 of valuation per year, on the average, might be added to the roll for each following year, until the bonds can have been paid off.

The report estimated the total cost of this improvement at $12.50 per acre, payable in installments scattered through twenty years, which expenditure will enhance the value of the land, at present market rates, $30 per acre and also allow the full use of a greatly augmented business profit for fifteen years of the twenty years. The works are described as simple but comprehensive in character, and well adapted to the popular needs.

In the report on the Perris district the location and surroundings are accurately described. The detail of the organization and the inclusion and exclusion of certain lands not originally included in its boundaries is set forth. The necessity of and adaptability of the land to irrigation is admitted.

In the present instance, it happens that the lands embraced within the district to be reported are not altogether unproductive without irrigation; inded, considerable portions of them have been cultivated in cereals for seven or eight years. In the more favorable seasons these have produced good crops, and have so far paid as wheat-growing lands; their marketable value for this purpose has ranged from $10 to $20 per acre. Moreover, vines and deciduous fruit trees start well and while young thrive on these lands; they only fail later in life, when the fruiting function exhausts the available moisture of the soil. The plain on which this district lies falls short of being practically a fertile region because of one failing; and that is, the want of sufficient moisture at the right time to mature crops.

It is doubtful whether, by the very best appliances and most perfect system, wheat-raising ever could here be made to support in comfort even its sparse population. This southern country has been, and will again be subject to series of very dry years. The wheat-growing practice on the San Jacinto plains has not yet passed through these. It commenced since such seasons have been experienced. Anticipation and hope of irrigation, though, have kept a population along from year to year, and during the past year, when this hope seemed to be approaching realization, there has been a very noticeable incoming of people.

The supply of this district comes from the Bear Valley reservoir, and the following is a copy of the contract between the parties:

WATER RIGHT AND DELIVERY CONTRACT.

This agreement, made this 20th day of January, 1891, between the Perris Irrigation District of San Diego and San Bernardino counties, Cal., a corporation, the party of the first part, and the Bear Valley Irrigation Company, a corporation, having its principal place of business at Redlands, San Bernardino County, Cal,, the party of the second part,

Witnesseth: That in consideration of the mutual covenants herein contained, the parties hereto agree as follows: The party of the second part hereby agrees to and does hereby sell to the party of the first part 16,000 of its class B acre water-right certificates, authorized by its board of directors by a resolution regularly passed on the 8th day of January, 1891, a copy of which resolution is hereto attached, marked Exhibit A, and made a part hereof, for the sum of $240,000 of the first irrigation bonds of said Perris district, bearing interest from January 1, 1891,* at 6 per cent per annum, payable semiannually on the 1st days of July and January; said 16,000 certificates to be delivered to the Perris Valley Bank at Perris, Cal., as soon as the same are lithographed and signed by the proper officers; to be held as collateral security for the payment of the irrigation bonds now authorized by said Perris Irrigation District, and including the said $240,000 in bonds to be paid for said 16,000 certificates, together with interest as the same matures.

The said party of the second part agrees to deliver to the party of the first part the water called for by said 16,000 certificates, as follows: The water called for by 800 of said certificates shal be delivered on the 1st day of April, 1891, as follows: The water called for by 266 of said certificates shall be delivered at the point marked A on the map of the Perris Valley, showing the boundaries of the Perris Irrigation District, hereto attached, and marked Exhibit 1, and made a part hereof; the water called for by 534 of said certificates shall be delivered at the point marked B on the said map marked Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1892, as follows: The water called for by 733 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,467 of said certificates shall be delivered at the point marked D on Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1893, as follows: The water called for by 666 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,334 of said certificates shall be delivered at the point marked D on said Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1894, as follows: The water called for by 666 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,334 of said certificates shall be delivered at the point marked D on said Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1895, as follows: The water called for by 666 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,334 of said certificates shall be delivered at the point marked D on said Exhibit 1.

The water called for by 7,000 of said certificates shall be delivered on or after the 1st day of April, 1896, and on or before the 1st day of April, 1899, as the directors of the said Perris District may hereafter determine, and at the point A the water called for by one-third of said certificates, and at the point D the water called for by two-thirds of said certificates.

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* This was subsequently changed to July 1, and the coupons for first six months' interest were cut and returned.

The party of the second part further agrees that it will sell to the party of the first part 4,000 * more of its said class B acre water-right certificates for $60,000 of the first irrigation bonds of the said Perris Irrigation District, provided the said party of the first part shall elect to purchase said 4,000 additional certificates on or before the 1st day of July, 1891. Said 4,000 certificates to be delivered to the Perris Valley Bank, at Perris, Cal., as collateral security for the payment of the irrigation bonds now authorized by said district, and the interest as the same matures, and will deliver the water called for by said additional 4,000 certificates on or after April 1, 1896, and on or before April 1, 1899, as the directors of said Perris Irrigation District may hereafter determine; the water called for by one-third of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by two-thirds of said certificates shall be delivered at the point marked D on said Exhibit 1.

The party of the second part further agrees that the sum provided to be paid on the 1st days of April and October in the said certificates shall commence as follows:

On 800 of said certificates on the 1st day of April, 1891; on 2,200 of said certificates on the 1st day of April, 1892; on 2,000 of said certificates on the 1st day of April, 1893; on 2,000 of said certificates on the 1st day of April, 1894; on 2,000 of said certificates on the 1st day of April, 1895; and the remainder of said certificates on the 1st day of April of each year, on the number of certificates represented by the water called for by the directors of said Perris Irrigation District, as hereinbefore specified between the 1st day of April, 1896, and the 1st day of April, 1899, and in any event the payment to commence on the balance of said certificates on the 1st day of April, 1899.

The party of the first part hereby agrees to pay the party of the second part the sums called for by said certificates as hereinbefore specified in accordance with the terms of the said certificates. A copy of said Class B acre water-right certificate is hereto attached, and marked Exhibit 2, and made a part hereof, and all the stipulations and agreements therein contained are hereby assented and agreed to by said party of the first part.

The party of the first part also agrees to pay the party of the second part $60,000 in its first irrigation bonds, for said additional 4,000 Class B acre water-right certificates, on or before the 1st day of July, if it shall elect to purchase said additional 4,000 certificates, and in the event of its purchase of said additional 4,000 certificates it will pay the sums called for on the 1st days of April and October on the number of certificates represented by the water called for by the directors of said district as hereinbefore provided.

And the party of the first part further agrees, that the said 16,000 Class B acre water right certificates, and said additional 4,000 Class B acre water-right certificates, if the same shall be purchased as hereinbefore specified, shall be deposited with the Perris Valley Bank, Perris, Cal., as collateral security for the payment of the irrigation bonds now authorized by said district, together with the interest on the same as the same matures.

The party of the first part further agrees that the point of delivery of the water called for in the year 1891, at point marked B on said Exhibit 1, may after the year 1891 be changed to the point marked D on Exhibit 1. And the party of the first part also agrees that it will construct, at its own expense, a steel pipe from the point B to the point C, as shown on Exhibit 1, of capacity sufficient to carry 150 inches of water, and from the point C to the point D of a capacity sufficient to carry 100 inches of water, and that the party of the second part shall have the right to flow through said pipe from the point B to the point C 50 inches of water, and that after the water hereinbefore specified to be delivered at the point marked B shall have been changed in its delivery to the point marked D, the steel pipe hereinbefore agreed to be constructed by the party of the first part shall belong to and become the property of the party of the second part.

It is understood and agreed that a sufficient part of the water to be delivered at the point A shall be at an elevation to cover the elevated lands on the east side of the San Jacinto River in said district, taking the elevation of the NE. corner of Sec. 25, T. 4 S., R. 3 W. as the highest elevation at which water is to be delivered, and provided that the elevation at said point of delivery shall only be sufficient to meet the requirements of said elevated lands, the lower to take at lower elevations.

And it is further agreed, that if in the future the party of the second part desires to change the point of delivery of water for said elevated lands, it shall have the option so to do; providing it shall not cause the party of the first part any extra expense to take such water from such changed point of delivery.

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* There is a supplemental agreement of recent date on this point, referred to in the report.

It is understood and agreed that the elevation or pressure of the point D shall be 1,650 feet.

In witness whereof the parties hereto have caused this agreement to be executed in duplicate the day and year first above written, in pursuance of resolution, passed by their respective directors, authorizing the execution of this agreement.

[SEAL.]

PERRIS IRRIGATION DISTRICT,
J. W. NANCE, *President.*
H. A. PLIMPTON, *Secretary.*

[SEAL.]

BEAR VALLEY IRRIGATION COMPANY,
AMMON P. KITCHING, *Vice-President.*
FRED E. HOTCHKISS, *Secretary.*

The farming area available is reported at 21,300 acres; the total area of the district is 22,800 acres.

The district will receive its supply through two main lines following a high line on either side of the valley occupied. The west side has the only system under construction, and it will cost altogether $157,438. The complete works for the district, including a town service system and water right, will cost $710,000, and, deducting the discount on the sale of bonds, will require an issue of $750,000 in bonds. The value of the land before the district formation was only from $10 to $20 per acre. The present selling value of the bare land is $50 to $75, subject to district assessments; while in a short time the unplanted land will bring $100. The following table, compiled by the engineer for the purpose of making an estimate of the debt-paying ability of the district, will show whether or not the district system will pay as a commercial investment on the part of those who buy the land and make farms, orchards, homes, and towns thereon.

	Value when irrigation commences.	Value in ten years.	Value in twenty years.
Farming lands	$2,000,000	$4,000,000	$6,000,000
Improvements	100,000	1,000,000	2,000,000
Town property and improvements	150,000	500,000	1,000,000
Total	2,250,000	5,500,000	9,000,000

The total cost of the enterprise per acre of the entire district will be about $31.10, payable in instalments running over twenty years. A comparison of these figures with the well known cost of water rights from private corporations must, in the opinion of this office, successfully refute the charge that an administration of irrigation by the community of irrigators increases the cost of the work.

In the Alessandro district the report goes back to a consideration of the irrigation conducted therein by the Spanish Mission priests; and notes that in this tract the "waters of irrigation were community property from the start, and lands were apportioned to the settlers." The district lies in the San Jacinto Valley and practically resembles the Perris district in all physical features. The water supply of this district is also from the same source—the Bear Valley reservoir.

The Alessandro district is in the undisputed zone of irrigation in southern California, and there are no equally large areas of land materially better adpated in surface and soils to cultivations of high class and by irrigation methods suited thereto.

Its agreement for water with the Bear Valley Irrigation Company is similar to that of the Alessandro district with the same company. The contract provides for the purchase of (acre) water right certificates and the delivery of water as follows:

Time of commencement	Number of certificates.	Number of acres.	Number of cubic inches.
June 1, 1891	4,000	2,000	500
Apr. 1—			
1892	6,000	3,000	750
1893	6,000	3,000	750
1894	6,000	3,000	750
1895	6,000	3,000	750
1896	6,000	3,000	750
1897	6,000	3,000	750
1898	6,000	3,000	750
1899	5,000	2,500	625
Total	51,000	25,500	6,375

The Alessandro irrigation district is practically an adjunct of the Bear Valley Irrigation Company's business, and is an exponent of its prudence in dealing with present conditions. Attention is called to the fact that the very best private methods applied to the irrigation district system has made no material difference in the cost per acre of the works projected. Alessandro is bonded at $30 per acre. The engineer says:

> The Alessandro district bonds having been issued to the extent of $765,000 for water delivered (distribution works thrown in, as it were), there is, as security for the loan contemplated by the law, property now assessed on a valuation of $2,436,036; of which $2,396,819 is the rated value of the farming lands. In my opinion these lands are now actually worth $3,000,000 as a minimum safe valuation. The prospective values are as follows:

	When irrigation well commences.	In ten years thereafter.	In twenty years.
Farming lands	$3,000,000	$6,000,000	$9,000,000
Improvements	150,000	1,500,000	3,000,000
Town property and improvements	200,000	600,000	1,200,000
Total	3,350,000	8,100,000	13,200,000

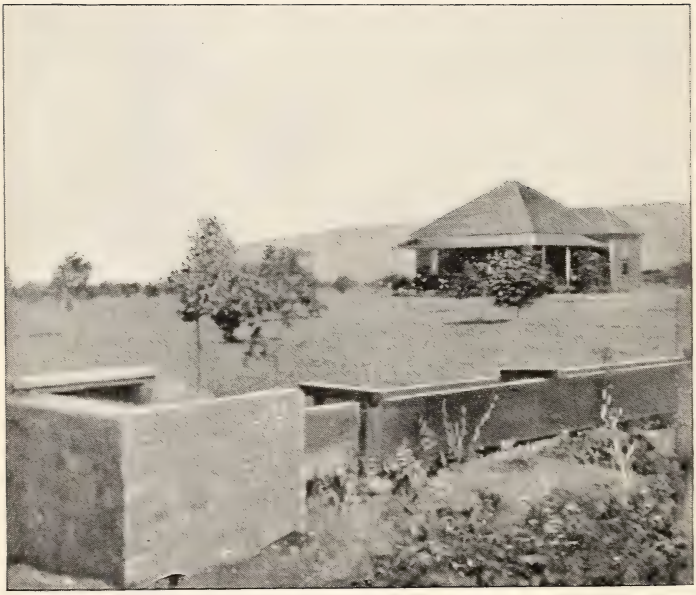
Continuing under the head of cost of irrigation, the report continues:

> If we assume, as is not unlikely to be the case, that main works for the full service, pro rata, of Alessandro district will cost the Bear Valley Irrigation Company as much as $17 per acre of the district area, the cost of this irrigation system, including the distributary works at $18 per acre, as already reported, when looked at merely from the engineering standpoint, will have been $35 per acre.

Taking lands worth certainly less than $20 per acre without water, and making them worth, immediately, really $150 per acre, works for the purpose might be regarded as cheap at much more than the above possible cost. The original land owner in this district will ultimately have paid for works and water rights, in purchase of land and in payment of bonds, $48 per acre, that is, $18 as part of land and cost, and $30 for water and delivery, interest not included.

There has been no litigation or adverse public sentiment in either the Perris or the Alessandro districts.

In closing this brief review of the work of Mr. Hall, it is only necessary to say that the figures presented are not always given in the same



Cement Hydrant and Flume Distributing Water on small Fruit Farm, Redlands, California.

relation presented by the author, for the reason that our purpose in their use is to a great extent different. Mr. Hall's work, viewed as the verdict of a valuation expert, is extremely well done. The seperate district projects are always indorsed, but under the lens of his scrutiny a pale reflection of doubt seems to be cast on the enabling law or principle of the system. The following extract from the Alessandro report will illustrate this:

> No such complete and perfect works of distribution as those going into Alessandro district ever would have been attempted but for the unification of the speculative advantage to be gained by them. These works are put in to sell the lands at high figures, and they will do it, in fact are doing it. There was no division of opinion on the question of building them, no community to be consulted, no vote to be had. The speculative company builds them, and gives them to the district. The purchasers of land, the settlers, pay for them in advanced land prices. The better works enhance actual values much more than the cost difference over ordinary construction. And, moreover, system and economy of construction keep cost much below that probable under community management. The other large land owners take the cue. The improvement becomes complete in the district. A specially desirable and thrifty class of settlers is thus drawn in, and district success is assured.

The propositions laid down in this paragraph are, in the light of recent events at least, admissible of argument. The character of the works in the Turlock and Modesto districts are in their way as thorough and able as the constructions referred to by Mr. Hall. Indeed, if the great areas to be reclaimed are considered (more than 550,000 acres of land), they are less costly and more important in a beneficial sense.

In northern California the conditions affecting irrigation have been very complex. The provision in the appropriation act of October, 1889, which reserved all irrigable land from settlement, has exercised, it is claimed on all hands, a very prejudicial influence on progress in this region. Mr. C. C. Hutchinson, of Susanville, Lassen County, a well-known western pioneer, is fully acquainted with the conditions of irrigation and intimately identified with its progress. He made a special trip to Reno, Nev., to advise with the special agent in charge of the irrigation inquiry, and, in discussing the region under consideration, said:

> I have had a great deal of experience in the settlement of this western region, and these mountain valleys in northern California are unquestionably adaptable to a series of prosperous agricultural settlements. These valleys are backed by mountains covered with timber and full of mines, which, when opened, must attract favorable attention. It is a very healthy region. The climate, take the year together, is considerably more equable and agreeable than that of Indian Territory or Arkansas. The development of northern California and Nevada is simply a question of irrigation.
>
> The first effect of the act of October, 1889, was to retard all work that had been commenced in new irrigation enterprises, and especially in Lassen County (in which I am interested) east of the Sierra Nevada Mountains, and in all northeastern California. At the date of the passage of that act, water was already stored for the irrigation of 10,000 acres of land; but the effect of the law was to prevent purchasers from taking any of these Government lands, and our hands were thus tied for more than a year, until the relief given by the Fifty-first Congress, when parties immediately began to come in from Illinois, Wisconsin, and Iowa, and take these desert lands. This United States survey proposed for irrigation purposes could have designated and reserved storage sites, and indicated the proper methods of canal distribution, without having to withhold from settlement all the lands that could be irrigated. If the power of reservation had been applied to the lands that could not be irrigated, or were above the reach of ditch water, it would have been sensible, for that would have afforded permanent water sheds for the irrigable areas, and would have also included the reservoir sites.
>
> This whole Sierra region is full of natural reservoir sites adjacent to, but separate and distinct from, the streams themselves. The proper position for a reservoir is not across the mouth of the natural stream bed, but in basins that may be fed by the stream without building a dam across its flow. A large amount of the dirt placed in dams has been washed out because of the unsafe method of making reservoirs in the beds of these mountain streams.
>
> Lassen and Modoc counties have an area of reclaimable land of about 1,000,000 acres, which is a conservative estimate. In general terms this land will produce

anything that can be grown in the northern half of the United States. We have mild winters, and there never has been a tree injured by winter cold, although we have had some killed by early or late frost.

The oldest irrigation enterprise in Lassen County is that known as the "Eagle Lake Land and Irrigation Company." The body of water which it is proposed to tap by means of a tunnel covers a surface area of 2,800 acres. It will give in depth an irrigation supply of three acre feet, and is an engineering proposition of perfect feasibility, provided the capital is available to construct the tunnel. During the past fall considerable activity has been shown and the company report the work well under way. Considerable rivalry exists between the Lassen projects, but they are all worthy of consideration. Accusations relative to dealings with desert-land entries circulate freely, but this office was not charged with an inquiry into such matter. The hydraulic projects as designed to serve reclamation purposes are within its province and among these that of Eagle Lake, Lassen County, is worthy of consideration.

The Honey Lake Valley Land and Water Company, of which Mr. Grunsky is consulting engineer, is interested also in reclamation within this County. It proposes to impound water to irrigate the land lying to the east of Honey Lake, by means of a dam in Long Valley of the following dimensions:

	Feet.		Feet.
Extreme height	96	Length of base, about	200
Width of base, about	500	Length at height of 85 feet	740
Width of top, about	20	Length at height of 96 feet	950

This will raise the water to a height of 90 feet above the present bed of the stream, or within 6 feet of the crest of the dam, and the water surface of the reservoir will have an area of about 1,081 acres with an average depth above the outlet gates of 30.4 feet, thus giving an available capacity in round numbers of 1,431,164,000 cubic feet, or 10,733,700,000 gallons, being about 100,000,000 cubic feet greater than that of the Bear Valley reservoir, in San Bernardino County, and nearly twice that of the Sweet Water, in San Diego County, two of the principal irrigation reservoirs in the country.

The three reservoirs in this region are at a general altitude of 4,100 feet. Observations of the evaporation from the Honey Lake reservoir during last July was 2 inches over the surface of the lake. Taking the experience of the Bear Valley people as a guide, it may safely be asserted that the loss by evaporation in this region will be compensated by the natural inflow of the summer.

The estimated duty of water for this reservoir is 1 cubic foot per second for 300 acres during the irrigation season of one hundred days.

The consulting engineer, Mr. Grunsky, whose experience and knowledge on this question is the result of almost exceptional opportunities of study, supports these opinions by the following statistics:

Redlands, San Bernardino County, uses 1 inch to 6 acres.
Rialto, San Bernardino County, uses 1 inch to 7 acres.
Etiwanda, San Bernardino County, uses 1 inch to 8 acres.
Cucamongo, San Bernardino County, uses from 1 inch to 8 to 1 inch to 10 acres.
Ontario, San Bernardino County, uses 1 inch to 10 acres.
Pomona, Los Angeles County, uses 1 inch to 10 acres.
Santa Ana, Orange County, uses 1 inch to 16 acres.
San Diego Land and Town Company (Sweetwater), San Diego County, uses 1 inch to 10 acres.
On the Ganges Canal, India, 1 inch to 6.6 acres is used.
On the Jumna Canal, India, from 1 inch to 5.5 to 1 inch to 6.1 acres is used.
At Valencia, Spain, 1 inch to 6.5 acres is used.

The consulting engineer estimates the cost of these works as follows:

Dam, 428,500 cubic yards earth, at 12½ cents		$53,562
Excavation for foundation, trench, 30,000 yards, at 12½ cents		3,750
Outlet works—		
Brick, 255 M, per M at	$5.00	
Cement per M at	5.00	
Lime per M at	2.00	
Mason per M at	5.00	
Helpers per M at	1.00	
Board per M at	1.00	
	19.00	4,845
Gates and placing same		1,000
Waste way and drop to creek		1,450
		64,607
Canals and ditches:		
2½ miles, 10 feet bottom, 4½ feet water at $2,750		$6,875
8 miles, 12 feet bottom, 3 feet water at $400		3,200
2 miles, 10 feet bottom, 3 feet water at $325		650
11½ miles, 10 feet bottom, 2 feet water at $220		2,530
28 miles, 7 feet bottom, 2 feet water at $160		4,480
57 miles, 4 feet bottom, 1 foot 9 inches water at $55		3,135
		20,870
100 feet flume at $2		2,000
		22,870
Tools, buildings, etc		12,075
		99,552
Temporary wasteway, 80 to 100 M feet lumber	2,000	
Incidentals	5,000	
		7,000
		106,552
Deduct value of plant		5,000
Total cost of works		101,552

The above estimate contemplates the purchase by the company of all teams, machinery, etc., that will be required in constructing the dam, which will prove the most economical method, insomuch as it calls for a smaller outlay than would be necessary in the event of hiring teams, and when the work is completed there will be left on hand a working plant.

The soil is a dark sandy loam of great depth and richness and retains moisture well. When irrigated it produces apples, pears, prunes, plums, currants, in fact, all the hardier fruits in great abundance and of superior quality. All kinds of vegetables, hops, corn, alfalfa, and nearly all forage plants do well and yield heavily. Among the fruits, the apples attain special excellence, and command the highest market prices.

In Lassen County a duty of 1 inch to 5, 8, and in one instance as high as 11 acres has been attained.

The proof by practice of this high duty of water will greatly simplify irrigation conditions in northern California.

Irrigation by means of stored water is always a very costly method, but if the able engineers who are in charge of this project demonstrate that 1 cubic second foot of water will irrigate 300 acres of ordinary farm land under favorable conditions it will bring stored water within the purchase of the farmer who depends for his subsistence on the growth of the less remunerative crops, such as are expected to be raised in this region. The three projects now under way in Lassen County expect to deal principally with irrigation districts and are so shaping their administrative policy.

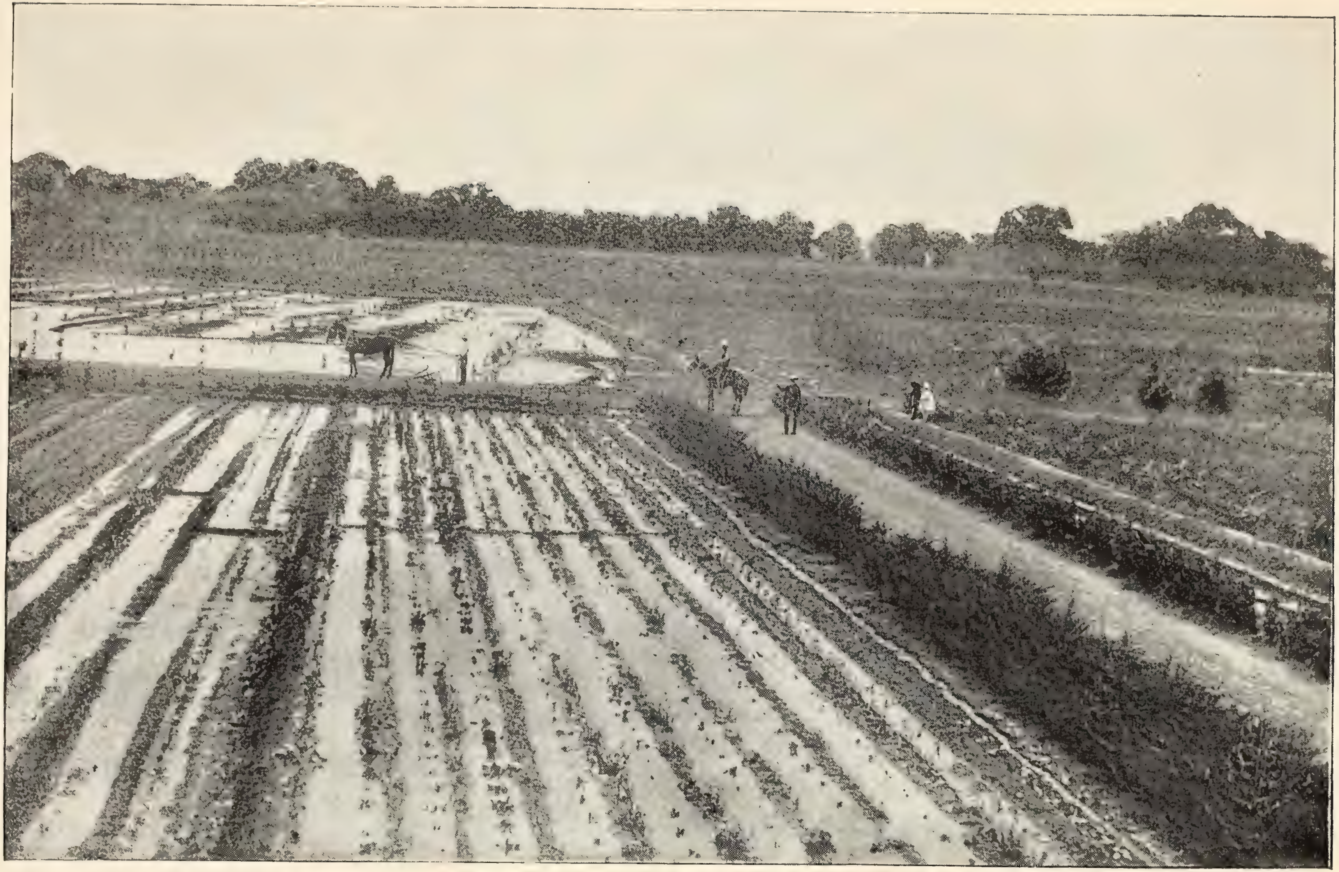
The three storage companies operating in Lassen County propose to deal directly with irrigation districts in the disposition of their water.

The royalty cost of water under the Eagle Lake plan will be $5 per acre; the annual cost about $1 per acre.

The growth of irrigation is further illustrated by the efforts of private parties to control the Chowchilla River. Water is now being impounded to irrigate about 40,000 acres on the Sharon estate. A dam 100 feet high, of uncoursed rubble masonry, 780 feet on the crest and 68 feet on the base of the upstream arch type, of radius at the center of 1,146 feet, gradually diminishing to 736 at the abutments, thus broadening the base on which it abuts against the hillsides, is thrown across the river at a favorable point in the cañon. Wasteways on either side of the dam of 15,000 second feet combined discharge are provided. It has a uniform batter of 1 in 25 feet below the first 10 feet. The crest, without counting the parapet, is 10 feet thick. Two outlets, excavated on either side of the dam in the solid rock, 20 feet above the base, in which steel pipes will be laid in cement, are provided; and in addition to these there will be another sluice laid 10 feet deep, in rock 6 feet above the bottom of the dam, in which a steel pipe will also be laid in cement. At an elevation of 420 feet above sea level 42,000 acre feet will be stored. The flood discharge of the Chowchilla is 1,500 second feet. The stream bed is used as a canal for 2½ miles, and water is diverted to the irrigation ditch 3½ miles long and of 300 second feet capacity by a weir overflow dam into a natural depression in a ledge of rock, which will be used as a part of the canal. This diversion weir is of masonry, 12 feet in maximum height and 400 feet along the crest. It is the purpose of the Sharon estate to hold the 42,000 acres irrigated in one ranch.

The Folsom Dam, built by the State of California by the use of convict labor, having been in process of construction for several years, was completed within the past year. It is a solid granite structure, 92 feet high, 65 feet thick at base and 20 feet at top, provided with a movable shutter or weir on top 6 feet high, to be raised by powerful hydraulic jacks operated by water power. The stone was quarried from the banks. Mr. Humbert was the engineer. The dam was constructed principally to develop water power for the penitentiary, but it having been shown that 500,000 acres of land may be irrigated from this source, the structure will probably find its most profitable use as a diversion weir to water the adjacent lands.

The Gage system of artesian wells and canals at Riverside has been referred to in former reports. A new system known as the Whittier ditch, modeled on the Gage plan, has been started near Whittier, 14 miles from Los Angeles. The conduit is 10 miles long, partly lined with cement and partly a covered wooden flume. Its construction is somewhat unique, and the supply is purely artesian, located in the upper San Gabriel Valley and near the foothills. The supply comes from very irregular strata, mostly sand and gravel, but no rock has been found by any of the drills. The first well sunk showed the following stratum:



Irrigated Kitchen Garden and Orchard at Tulare, California.

	Feet.
Sand to	10
Coarse gravel to	20
Clay to	23
Sand to	53
Clay to	56
Gravel to	100
Clay to	110½
Coarse gravel to	116½
Clay to	118
Gravel to	120
Clay to	121
Sand and gravel to	128
Clay to	131
Sand and gravel to	168
Clay to	179
Sand and gravel to	200

This is the deepest boring. Although these wells are sunk within 100 feet of each other, no two wells show the same strata. There are fourteen in all, with 7-inch bores. The pressure has not been measured, but a flow of 3 inches above the pipe from all is steady and constant. In utilizing this water the pipe is brought up into a closed box casing, and from there emptied into a closed wooden ditch which conducts the water to the cement ditches for distribution. At the date of examination no system of distribution had been provided, for the company was engaged in developing their water supply. It may be generally assumed that this system can be developed throughout the San Gabriel Valley and in valleys of similar local conditions. Already 400 miners' inches of water have been obtained, and it is expected that 1,000 inches of water will be ready for irrigation next year.

The great value of water in southern California, while it has made storage possible with profit to the irrigator, has also stimulated a close inquiry into the extent and capacity of the phreatic supply that may be developed from the cienegas, the lost flows of streams, or the underflow of others, and from shallow drainage under pressure or deeper artesian sources. Besides the wells at Whittier the engineer of this scheme is running a drift tunnel into the bed rock, and is meeting with such success as to promise ample reward. The land to be irrigated by this water has heretofore been range land for cattle and sheep.

ANSWERS FROM CORRESPONDENTS.

The following summaries are made from replies received to circulars sent by this office:

FRESNO COUNTY.

Firebaugh (post-office), J. W. Schmitz (October, 1891):

Water supply: For Poso Farm, from "San Joaquin and Kings River Canal and Irrigation Co.;" for Eastside (Chowchilla and Riverside canals), San Joaquin River.
Works: Poso ditch, 16 feet on bottom, 20 feet on top; Chowchilla canal, 25 feet on bottom, 34 feet on top; Riverside Canal, 30 feet on bottom, 39 feet on top. Head gates, Poso Farm, 1; Eastside, 3.
Cost per mile: Poso Canal, $400; Chowchilla, $2,440; Riverside, $800.
Average yield per acre: Alfalfa, 6 tons; grain, 15 bushels.
Average cost per acre for annual maintenance and repairs, $1.
Average cost per acre for preparing land for cultivation under irrigation: For grain, $8; for alfalfa, $7.50; for grass land, $2.
Area under ditch: Poso Farm, 4,800 acres; Eastside, 10,500 acres.
Area under cultivation: Poso Farm, 4,200 acres (one-sixth in grain, balance alfalfa); Eastside, 4,500 acres (200 acres in grain, balance in alfalfa).

Fresno (post-office), J. S. Dove (October 16, 1891):

Has 140 acres under cultivation. Water supply, from a canal company that obtains its supply from Kings River.
Cost of water supply per acre, 62½ cents.
Cost per acre for preparing land for cultivation under irrigation: "Some of the lands, not level or smooth, cost from $10 to $20 per acre to prepare for irrigation."
Chief products under irrigation: Raisin and wine grapes, oranges, apricots, peaches, pears, etc.; alfalfa.
Value of product per acre: "Sold his raisin grapes on the vines for $18 per ton—netted $700 per acre (3-year old vines); alfalfa (within 5 miles of town), $40 to $50 per acre. Six crops cut in the season by some of his neighbors."

Fresno (post-office), Wm. McWhorter, secretary, "Sunset Irrigation District."

Water supply: Kings River, "supply 5,000 cubic feet from April 1 to June 1."

Works: Main canal 110 miles proposed (works not yet constructed).

Estimated cost (section 1), 13 miles, $850,000; (section 2) 50 miles, $100,000; (section 3) 47 miles $47,000.

Area to be covered: 360,000 acres.

Interest on bonds and current expenses this year: 3 mills per cent.

Fresno (post-office), J. C. Shepherd (September, 11, 1891):

Fowler switch canal: Source of supply, Kings River; supply from January to August; river runs low in August, and other canals have prior rights.

Works: 30 miles main canal; 40 feet on bottom, 80 feet on top, 5 feet deep; two head gates; one waste gate; no reservoirs.

Area under ditch: 250,000 acres (portion of same land may be also covered by other ditches).

Cost per mile: $5,500.

Average cost per acre of irrigation works: Ditches, etc., $5.

Average cost per acre for preparing land for cultivation under irrigation, $12.50.

Average cost per acre for annual maintenance and repairs, 25 cents.

Staple products under irrigation: Apricots, peaches, grapes, and alfalfa.

Average value of product per acre: Fruit, $75; alfalfa, $50 (vines have not yet reached full bearing.)

Madera (post-office), Thomas E. Hughes (October, 1891):

"Madera Canal and Irrigation Company;"—water supply, Fresno River, and a branch of San Joaquin River turned into it. Canal taken out after river reaches the plain or level lands.

Works: 100 miles canals; 30 to 40 feet on bottom; 50 to 75 feet on top. One dam in mountains on branch of San Joaquin River; and one brush dam at head of canal; 150 to 200 distributing head gates throughout the system. One reservoir contemplated.

Area under ditch: 20,000 acres (under system at present); under cultivation, 13,000 acres.

Cost per mile: $50 to $100 (after reaching the plains). Estimated cost of reservoir, about $100,000.

Cost of water supply to user per acre, $1. Annual rental cost, $1.

Average cost per acre for preparing land for cultivation under irrigation: About two-thirds of the land between San Joaquin and Kings rivers cost from $2.50 to $10; one-third, from $10 to $30 to prepare for irrigation.

Cost per acre for annual maintenance and repairs: About $100 for 640 acres.

Estimated value of product per acre: Raisin grapes, $50 to $200; alfalfa, $50 to $100 (grain on same land, $10 to $25); tree fruits, $50 to $200.

["It is estimated that in Fresno County between the San Joaquin and Kings rivers, 575,000 acres are now irrigated or are affected by irrigation. About 75,000 acres of land, mainly in grapes, fruit, and alfalfa has, for the last four to six years, needed no surface irrigation on account of the lands having been sufficiently subirrigated by the general seepage from the canals. Twelve years ago surface water could be found only at a depth of 50 to 60 feet; it is found now at a depth of 4 to 7 feet."]

KERN COUNTY.

Bakersfield (post-office), J. W. Thompson (October, 1891); has 40 acres under irrigation.

Water supply through Calloway Canal from Kern River; water brought by a lateral ditch 5 miles long, 20 feet wide; head gates of ditch, 3 (one at canal head of ditch, two on farm).

Cost per mile of lateral ditch, $500.

Cost of water supply to user per acre, $1.50.

Average cost per acre of irrigation works: Ditches, $2 50.

Average cost per acre for annual maintenance and repairs, 10 cents.

Average cost per acre for preparing land for cultivation under irrigation, $3.

Staple products under irrigation: Raisins, peaches, pears, prunes, plums, apricots, nectarines, figs, etc.; alfalfa, hay, live stock, barley, wheat, potatoes, and garden vegetables of all kinds.

Estimated value of annual product per acre, $100.

Area under Calloway Canal, 200,000 acres; under cultivation, 45,000 acres.

In reply to circulars and other sources, the following general data, relative to this county, have been compiled:

Works—During 1891 about 100 miles of canals have been constructed. Over 1,000 miles were previously in operation. The new canals are large and important. The Kern Valley Water Company's canal is 125 feet wide at top and 22 miles in

length. It carries 6,000 cubic feet of water per second. The Kern and Tulare irrigation district have made surveys for a new canal to irrigate 150,000 acres of land. The "78" Canal Company, just incorporated, will build, during 1892, a canal to irrigate 150,000 acres, known as the "Weed Patch," at a cost of $750,000.
Of new land 3,000 acres were set out during 1891, to fruit trees and grape vines.

LASSEN COUNTY.

E. R. Dodge, a director of "Eagle Lake Land and Irrigation Co." (September, 1891); reports work in progress on a cut into Eagle Lake (2,800 acres), which will give 3 acre feet for irrigation purposes:
Estimated cost of water supply to user per acre, $5; annual rental cost, $1.

LOS ANGELES COUNTY.

Azusa (post-office), W. R. Powell (October 1891):

Local water supply (1st) San Gabriel River, ($\frac{306}{720}$ of the first 1,700 inches of the river-water surplus goes to other systems); (2d) a mountain stream.
Works: Loose dam made yearly; 900-foot tunnel; open ditch to carry 1,000 inches; about 150 gates.
Area under ditch, 4,000 acres; under cultivation 3,000 acres.
Average cost per acre for first-class works in locality, $15.
Average cost per acre for annual maintenance and repairs, $1 (to include pay for water tender).
Products: Oranges, lemons, strawberries, etc.; alfafa, potatoes, etc.
Average value of product per acre, $50 to $700.

Downey (post-office), T. J. Kerns (October 3, 1891):

Average cost per acre in his neighborhood, for preparing land for cultivation under irrigation: Plowing, $2; harrowing, 50 cents (soil is a rich, sandy loam easily cultivated).
Cost per acre for irrigation works, ditches, etc.: About $1 in the immediate vicinity; on the mesa and foothills is more, in some places reaching $20. The ditches generally are easily constructed.
Average cost per acre for annual maintenance and repairs: 20 to 25 cents per acre will clean ditches twice yearly.
Products under irrigation: Corn, barley, alfalfa, sugar cane, sugar beets, sweet and Irish potatoes, and all vegetables, oranges, lemons, figs, and all deciduous fruits, English walnuts, etc.
Average yield and value of same: Alfalfa, cut 6 times yearly, 1 to 2 tons per acre each cutting; sells in the shock at $7 per ton; corn, 45 to 100 bushels, selling at $1.45 per 100 pounds.

Los Angeles (post-office), J. W. Potts (October 3, 1891):

Water supply, Los Angeles River: Area irrigated from it about 15,000 acres; flow of river in the fall (before the winter rains) about 75 cubic feet per second. Water and works (including 2 reservoirs) owned by city; cost of works, about $30 per acre for lands irrigated; water sold at $2.50 per day for a "head" of 100 miner's inches; general duty of water, 1 miner's inch for 10 acres (steady flow). Estimated irrigable capacity of river, if winter supply was properly stored in reservoirs, 150,000 acres.
Average cost per acre for preparing land for cultivation under irrigation (plowing, etc.), $2.50.
Staple products under irrigation: Oranges, lemons, grapes, peaches, pears, etc. (everything suitable to the climate).

[Corn is generally raised in the wet lands supplied by underground seepage; wheat and barley by means of winter rains; fruits do well on the foothills without irrigation.]

Average value of products per acre: Oranges, $500 to $1,000; lemons, $1,000 to $1,500; peaches, pears, apples, $200 to $500; (two or three crops of different products are raised yearly.)

Los Angeles (post-office), F. A. Atwater (October, 1891): Farm at Clearwater on "California Coöperative Tract."

Two years ago had from 2,500 to 3,000 acres under ditch; 1,000 acres cultivated by means of 3 to 4 miles of ditch, 4 feet on bottom; 10 to 15 feet on top; supplied from New River; course of river has changed and ditch of no use.
Only irrigation in that locality now by means of fifteen or twenty artesian wells, from 140 to 350 feet deep, costing from $150 to $500 each; about 300 acres irrigated.
Cost per mile for preparing land for cultivation under irrigation, $2.50 to $3.

Staple products under irrigation: Corn, potatoes, onions, and alfalfa.
Estimated value of product per acre, $20.

Pasadena (post-office), M. H. Weight (October 3, 1891):

City of Pasadena and adjoining lands directly tributary to it, comprise about 14,000 acres; about 7,000 acres in orchard and vineyard; city about 2 miles square, 1,600 acres of which is in orange, lemon, and deciduous fruit trees.

Water supply: Springs about 3 miles north of city in Sierra Madre Mountains; by means of iron pipe lines, to cemented reservoirs, thence distributed through same kind of pipe, ranging in diameter from 1 to 10 inches.

Capacity of springs: They furnish at present not less than 350 miner's inches per second, continuous flow; a much larger supply is being developed by means of tunneling and by constructing a submerged dam to utilize the large supply of water from the springs which now sinks into the sands; new system of reservoirs cnotemplated.

The pipe lines are being continually improved, extended, and enlarged.

C. H. Richardson, C. C. Thompson, T. S. C. Lowe, among others of Pasadena, testify as to—

Acreage in fruit in Pasadena proper, South Pasadena, and adjacent foothills, about 8 square miles, or 5,100 acres. Of this area 1,600 are planted to orange trees (budded), over five years old; 800 acres are in seedlings and about 150 acres are in bearing trees less than five years old, making in all for oranges at least 2,500 acres. In deciduous fruit trees there are 1,600 acres, 12 acres in walnuts, 20 in olives, and an acreage sufficient for 1,000 lemon trees. All are irrigated.

Product and value in oranges from $200 to $400 net per acre in 1891. On a 50-acre orchard adjacent to Pasadena the net profit in green fruit for last season was $9,000, or $180 per acre. Dried fruit would have made larger returns.

San Gabriel (post-office), A. Scott Chapman (October 5, 1891):

Water supply: Artesian wells; area irrigated, 150 acres.

Well, 400 feet deep; dirt reservoir, 8 feet deep, 120 feet diameter.

Cost of well and reservoir, $1,500; cost of reservoir, $215. Will supply 60 acres ($25 per acre).

Cost per acre for preparing land for cultivation, $10 (clearing land of brush). Total cost per acre for well, reservoir, etc., and preparing land, $35.

Staple products under irrigation: Oranges, lemons, walnuts, vegetables.

Average yield per acre: Oranges, 400 boxes; walnuts, 4,000 pounds.

Whittier (post-office), A. L. Reed (September, 1891):

Water supply: Artesian wells and springs; 14 artesian wells, 80 to 200 feet deep, develop 4½ cubic feet per second; springs develop 3½ cubic feet per second.

Works (not yet completed): 11 miles main conduit (cement and concrete); bottom width for 9 miles, 4 feet; top, 6 feet; depth, 3 feet 4 inches; for 2 miles, bottom width 3 feet 4 inches, same depth. Head gates, 1 set (of 2); waste gates, 2; waste-gates with sand boxes, 2. Flumes, 6,200 feet (wooden, on piles and trestle).

System not yet in working order.

MERCED COUNTY.

[Data for this county, compiled from various sources in answer to circulars, is especially interesting in its bearing upon the organization of fruit-growing colonies. There are now fifteen in the county, and the briefed particulars are as follows:]

Name.	Area of colony.	Area planted.	Name.	Area of colony.	Area planted.
	Acres.	*Acres.*		*Acres.*	*Acres.*
Archer	320	80	Livingston	320	110
Ashe	900	....	Mitchell	280	120
British	5,840	100	Rialto	320	....
Bubach	1,280	510	Rotterdam	3,190	1,500
Deane	6,020	320	Towne	960	70
Dos Palos	6,000	6,000	Yosemite	640	260
El Capitan	1,920	185			
Honitos	210	25	Total	22,200	9,280

Nearly all of the planted area reported is laid down in fruit—almonds, apricots, berries, nuts, olives, peaches, pears, plums, prunes, and raisin grapes. In addition to the foregoing about 1,400 other acres have been planted in fruits.

The Merced Canal and Irrigation Company represent $3,000,000 of capitalization. The main canal is 50 miles in length; principal source of supply is the Merced River. The canal carries 4,000 cubic feet per second. There are two tunnels on route, with a total length of 8,500 feet. An open reservoir is known as Lake Yosemite. Its cost has been $2,000,000. The chief source of supply is the Merced River, fed by mountain snows.

J. L. Dickinson, of Los Banos:

Water supply from San Joaquin and Kings River.

Canals of large size, parallel to each other, 50 to 70 miles in length. Farms and orchards supplied by small distributories from main ditches.

Cost to user, $2.50 per acre; preparation of land, from $2 to $5; for irrigation, from $1 to $2; annual rates, not to exceed 15 cents per acre.

ORANGE COUNTY.

E. E. Edwards, Orange (post-office), September 22, 1891:

Water supply: Santa Ana River; flow sufficient for 36,000 acres.

Works: Open ditches and flumes; main ditch supplying neighborhood, 20 to 26 feet on top, 10 to 14 feet on bottom; in all, 123 miles of ditches, etc. Three head gates; built in 1877.

Artesian wells: 250 flowing in county, used for domestic and stock purposes. Use for irrigation just beginning in some neighborhoods.

Cost of main ditch from $800 to $7,000 per mile; average cost per acre, $17.50; annual cost to use for same, $6.60; cost per acre of repairs, etc., 50 cents.

Acreage served: Under ditch, 36,000 acres; under cultivation, 30,000.

PLACER COUNTY.

Jonas J. Morrison, Loomis:

Water supply is from South Yuba and Bear rivers, fed in the Sierra Nevada by snow and mountain springs. This is a foothills region, and all is under ditch. Our ditch (the South Yuba) carries 2,000 miner's inches, and usually fails us in July and August because the ditch is not large enough; supply is sufficient if latter was remedied.

Cost: We purchase from owner of main ditch at rate of 45 cents per miner's inch per annum. A miner's inch irrigates, with us, according to soils, from 5 to 10 acres. Annual maintenance is $1 per acre.

Cost of clearing land is about (for general farming) $20 per acre; for orchard clearing, trees, and planting.

Area: In this section 10,000 acres are under ditch; 4,000 under cultivation.

Products: Chiefly all varieties of deciduous fruits.

SACRAMENTO COUNTY.

Secretary of Natoma Water and Mining Company, Folsom (post-office):

Water supply is south fork of American River.

Works are a canal with capacity of 42 cubic feet per second, 17 miles of main, and 25 of small or lateral ditches.

Cost of per mile from $200 to $500. Cost of preparing land for cultivation, $5 to $50 per acre; the same for irrigation works per acre; of annual repairs and maintenance, from $2 to $10. Charge to consumer (royalty), $5 per acre.

Acres under ditch, 20,000; under cultivation, 1,200 acres.

Products: Table and wine grape, deciduous fruits, and vegetables.

SAN BENITO COUNTY.

George T. Elliott, Hollister (October, 1891):

Water supply: San Benito River and artesian wells; latter unlimited in supply.

Works: 50 miles of ditches, besides wells, reservoir of 30 acres; dam 120 feet long, 10 feet high; 50 head gates. Two systems in use, 10 miles apart. Cost of main ditch, $1,000 per mile; reservoir, $5,000; of wells from $150 to $1,000 each.

Acreage served: Under ditch, 10,000; under cultivation, 3,000 acres.

Cost of irrigation, $5 per acre; annual rental, $4 per acre; cost of repair, $1.

SAN BERNARDINO COUNTY.

[Data from several sources give the horticultural growth for the past year.]

There were planted of citrus trees, 9,454; of deciduous, 3,274; of vines, 2,808; a total of 15,486. The largest number planted by any one colony or settlement was at Riverside, 4,000 citrus trees. Redlands planted 1,200 of such trees, and 150 deciduous. At Alessandro, the new settlement under Bear Valley service, there were 1,100 citrus and 1,000 deciduous trees, with 100, vines planted. Highland, Ontario, and South Riverside were next in extent of planting. The fruit acreage of the county is reported at 41,440, an increase for one year's planting of 20,437 acres, or nearly as much as was previously cultivated for fruit. The division is as follows:

	Acres.		Acres.
Orange	22,871	Apple	250
Lemon	1,800	Olive	240
Peach	3,874	Nuts	250
Apricot	2,000	Vines	8,688
Pear	577		
Prune	550	Total	41,440
Fig	340		

F. C. Finkle, C. E., San Bernardino, states cost of preparing citrus orchard land at from $100 to $200; for other trees and vines, $50; for alfalfa, $10 per acre. Cost of irrigation works, from $10 to $20 per acre. Production is stated: Oranges and lemons, 300 boxes; deciduous fruits, 5 tons; raisins, 100 boxes; alfalfa, 4 tons per acre.

Robinson J. Jones, San Bernardino (post-office), September 24, 1891:

Water supply at Etiwanda is from two cañon streams, averaging 287½ miner's inches. It has been as high as 502 inches.

Works consists of two flumes, connecting with and discharging into reservoir. Ten miles of fluming Reservoir 20 feet cement box, fitted with eight distributing lines. Timber dams in cañons divert water into flumes. Concrete pipes, with standpipes at every 10 acres, are used for distributing supply. Pressure is gained by a 10-foot fall in each 660 feet.

Acreage served and under cultivation, 1,100 acres.

Cost of water per annum to users, 75 cents per acre. Estimated cost of main irrigation works, $10 per acre. Orchard service borne by farmer.

Products: Fruits and vegetables, chiefly oranges, raisins, and lemons. Average return per acre, $125.

Solomon Neumann, Messina (post-office), (September 25, 1891), Highland, and East Highland:

Cost of preparation has been $75 per acre. West Highland cost is not over $20 per acre. These areas form what is known locally as the Highland district.

Cost of works, about $100 per acre; annual cost, about 75 cents for same to user.

Acreage: Under ditch, 6,000; under cultivation, 2,000 acres.

Products: Fruits, the profits of which per acre will be from $800 to $100, according to varieties and age of trees.

E. M. Hatch and H. H. Morgan (the latter is president of San Antonio Water Company), Ontario (post-office), September, 1891:

Water supply: San Antonio Canon, creek and tunnel.

Works and their character: Tunnel half a mile and cement ditch one-half mile in length; 62 miles of cement piping underground; one head gate; main pipe, 3 feet in diameter. Pipes cost for laterals about $1,200 per mile.

Cost: Preparing land about $20 per acre (Mr. Hatch says from $20 to $100); cement ditch for 10 acres, Mr. Hatch states, will cost $175. Cost of water per acre is not less than $100; annual cost to user about 75 cents per acre.

Acreage served: Under water, 4,500; under cultivation, 3,000 acres.

Messrs. Theodore C. Clark (general manager Bear Valley Company), F. G. Ferand, H. W. Allen, H. H. Sinclair (secretary South Fork Ditch Company), T. L. Lyon, C. J. Monson, and E. G. Judson write from Redlands (September and October, 1891):

Water supply: Santa Ana River and Bear Valley reservoir.

Area served: Under Crofton system, 3,000 acres under ditch and 1,800 under cultivation. Under all systems, served by Bear Valley, etc.: Under ditch about 18,000 acres, under cultivation about 13,000; contracts, when all are served, will bring 34,000 acres under ditch. Several other districts are served by the same system.

Cost of preparing land, from $10 to $40—latter for fruit; some rate cost as high as $50.

Cost of irrigation is variously estimated at from $15 to $40 per acre; probably $30 will be a fair estimate; annual rental is from $1.50 to $6 per acre; water royalty is rated from $30 to $75 per acre.

Return per acre averages: Deciduous fruits, $125 per acre; oranges, according to age of trees, from $100 to $800 net; alfalfa, 6 to 10 per year, $8 per ton.

A. E. Sterling, Redland (post-office), for Palm Valley Water Company (September 24, 1891):

Water supply: Whitewater and reservoir.
Cost of works: Main stone ditch of 10 miles, $14 per acre; private ditch (stone) or lateral flumes, $12 per acre.
Annual cost, about $1 per acre.
Area served: Under works, 3,000 acres, reclaimed from upper part of Colorado desert; under cultivation, 500 acres.
Products: All early fruits and fine vegetables, oranges, figs, grapes, dates, etc., all do well. All mature very early.

W. A. Coyrell, secretary Riverside Water Company (September 26, 1891):

Water supply: Santa Ana River, Warm Creek, and artesian wells; 80 cubic feet per second.
Cost of preparing for cultivation, land being level, $20 per acre.
Cost of irrigation: Works and water rights, $60 per acre; annual maintenance, $6 per acre.
Works, nature of: 40 miles of flume; 9 miles canal; 100 miles of lateral ditches, flume, stone and iron pipes; three head gates; two tunnels 3,380 feet long, 8 feet wide, 6 feet high; 10,400 feet of flume, 4 feet deep, 8 feet wide.
Cost of works: Main canal, from $1,000 to $10,000 per mile; of tunnels, $5 per lineal foot. In all other estimates make total cost $750,000.
Under ditch, 12,000 acres; under cultivation, about 7,000.
Annual product per acre (estimated): For citrus fruits, $500; for raisins, $100; for alfalfa, $20 per acre.
Products: All semi-tropical fruits, grain, alfalfa, fine vegetables.

George Dole, Riverside, (September 25, 1891):

Area under ditch, 17,675; under cultivation, 8,000 acres.
Cost of preparation and water for cultivation, $50 per acre.

A. H. Naftzger (president East Riverside Water Company), Riverside (post-office), F. C. Finkle, C. E., San Bernardino (post-office):

Water supply: Chiefly artesian wells, sufficient for 10,000 acres; present supply, 6 cubic feet per second.
Cost of preparing land, $25 per acre.
Cost of water, $75 per acre; annual rental, $2 per acre.
Works, nature of: Iron pipe line, 24 inch; 27 head gates; 16 miles of ditches; 3 of main ditch; pipe line cost $12,000; ditch, $2,000 per mile.
Under ditch, 3,000 acres; under cultivation, 500 acres.
Products: Oranges and lemons; trees not yet bearing.

The Riverside Water Company has 24,000 shares, at a par value of $10, or an original capitalization of $240,000. Each landowner in the 10,000 acres to be served took two shares at the time of organization, balance being held for purchasers of unimproved land. When fully sold each acre will be represented by two shares, transferable only with the land. The users are thus at all times the owners of the works. Each irrigator is entitled to all the water he needs, the regular rates, therefore, being fixed by the board of city trustees. The courts have sustained the issue of stock to unimproved land. Cost of works is reported at $900,000; cost per annum, $6 per acre. Artesian water under pressure is supplied for domestic purposes.

The Gage system, for the supply of Arlington Heights and other additions to the original Riverside, consists of 12,000 acres in two equal tracts, served by 38 artesian wells, whose supply is derived from the underflow of the upper Santa Ana River. These wells are sunk to various depths of from 150 to 500 feet. The water flows into the Santa Ana River, and thence through a canal, which is filled by a diverting dam. There are three other land companies which have constructed reservoirs and pipe systems, at a cost of $100,000. The Gage works and lands have been sold for $1,000,000 to a company.

Acreage "under water" in the valley of which Riverside is the center is as follows: Riverside, 10,000 acres; Gage canal, 15,000; South Riverside, 6,000; North Riverside canal, 7,500; Vivienda pipe line, 5,000; Rincon ditch, 4,000; a total of 47,500 acres.

F. C. Finkle, San Bernardino, engineer Jarupa system (January, 1892):

Water supply: Santa Ana River and cienegas (wet subsoil); 30 cubic feet per second at present.
Works: Main canals, 18 miles; small reservoirs for distributary purposes; 74 head gates; 200 miles of laterals; subcanal into cienegas 1 mile, 5 to 20 feet deep.
Cost of: drainage, cut or sub-canal, $30,000; earth canal, $11,000; cemented ditch, $3,600; flume and trestlework, $10,000—in all, $54,600.

Area served: Under ditch, 10,000 acres; under cultivation, 3,000. Cost of supply, $50 per acre; annual rental, $2 per acre.

SAN DIEGO COUNTY.

D. Goechenauer, San Diego (post-office), 1891:

Fruit-tree planting during 1891 has been on an extensive scale. Of citrus and deciduous trees about 900,000 have been planted during the year. The fruit bearers for 1892 will not be less than 500,000 trees, an increase of 200,000 for the past year. During 1891, out of San Diego city there were shipped 2,820,000 pounds of raisins, or about 142 cars, as against 88 cars last year. There were 66 carloads in 1890 from the San Diego Bay section. Of this total, Spring Valley and El Cajon furnished 12 carloads, and Sweetwater, Paradise, and Tia Juana valleys furnished 42 carloads. The other 10 cars were raised in Jamul, Lyons Valley, Otay, National Rancho, and other tributary valleys.

SAN JOAQUIN COUNTY.

J. D. Huffman, Lodi (October 13, 1891):

Water supply: The Mokelumne River.

Works: Main canal, the Woodbridge, at present 12 miles in length; large dam across the river, made of piles and timber, of which 500,000 feet have been used. Piles have been driven from 13 to 28 feet; crest of dam 6 feet below low-water mark. There are 22 gates, by closing which the canal can be flooded. The dam, which is on the weir or overflow principle, will permit the high water to flow over its crest; the channel is 200 feet in width.

Area to be served is now 50,000 acres, but it is expected that canal and reservoir will serve 170,000 acres.

SONOMA COUNTY.

H. J. Schroobeda, Petaluma (October, 1891):

All irrigation is chiefly from wells, and confined to fruits and gardens. There are 5 miles of ditches.

Cost per acre estimated at $20; total cost of such works $24,000 in my neighborhood.

Under irrigation here, 45 acres. Water plane, 10 feet below surface; water costs about $20 per month. Product is rated at $250 per acre.

TULARE COUNTY.

N. W. Motheial, Hanford (October, 1891):

Water supply: Kings River.

Ditches serving neighborhood are the People's, Last Chance, Lake Side, Lower Kings River, and Mussel Slough. People's Ditch is 25 miles in length, 40 feet at bottom, 5 deep, and falls 1 foot to the mile. These ditches cover 125,000 acres.

Ground is level no timber; ditching cheap; preparing land easy. Cost, $1 per acre; with ditch, $1.50; annual maintenance, 50 cents per acre; cost per mile, in all about $3,500. One dam in river, cost $7,000; one head gate.

Under cultivation (People's Ditch), 25,000 acres. Crops: Corn, wheat, alfalfa, deciduous fruits of all kinds; some citrus orchards in sheltered places.

P. Y. Baker, director in Alta irrigation district (Tulare and Fresno counties), Tulare (September 22, 1891):

Water supply: Kings River, mountain stream fed from higher Sierras; carries 30,000 cubic feet per second during season from May to August.

Works: Canal 100 feet on bottom, 18-inch fall, slope 3 to 1, 5 feet of water; numerous laterals; 1 main head gate; 628 farm gates.

Cost of main canal, $1,200 per mile. System has cost district $3.75 per acre in 6 per cent twenty-year bonds.

Area under ditch, 130,000 acres; under cultivation, 124,000. Organized under district law.

Cost of water: 42 cents per acre per annum.

Cost of cultivation: Meadow and fruit land, $10 per acre.

Product per acre: $25 to $40 in value.

Crops raised: Wheat, oats, barley, corn, potatoes, vegetables, raisins, prunes, peaches, apples, nectarines, oranges, lemons, olives, apricots, pears. wine grapes, alfalfa, blue grass, nuts of all kinds.

George H. Weaver, secretary "Alta" district, Dunbar (September, 1892):

Water supply: Kings River. District organized under Wright laws.

Works: Head gate; dam; 25 miles of main ditch; many more of laterals; one reservoir of 100 acres; 1 head gate.
Cost per mile, $600.
Area under cultivation, probably 40,000 acres.
Cost of supply to user by tax levy, 38½ cents. Under district system tax levy is 80 cents on $100 of valuation; interest, 20 cents; maintenance, 13 cents; administration, 5½ cents per acre. Cost to user before district formed was: royalty, $5 per acre; annual rental, $1 per acre.

E. A. May, secretary Poplar Irrigation Company, Tulare (October, 1892):

Cost of preparing, $9 per acre, under favorable circumstances; with ditches for irrigation, $15 per acre.
Cost of water to user, from 50 cents to $1 per acre per annum.
Area cultivated by Poplar Ditch, 1,400 acres.
Products: Chiefly alfalfa, hay, vegetables, fruits, raisin grapes. Yield: Fruit, from $100 to 250 per acre; vegetables, from $200 to $300.

VENTURA COUNTY.

W. W. Blanchard, Santa Paula:

No regular irrigation.
Small ditches and wells are used for irrigating gardens, orchards, and alfalfa; but chiefly for stock and domestic purposes. Citrus fruits are irrigated.

YUBA COUNTY.

J. McFarlane, secretary Brown Valley irrigation district, Brown Valley (post-office), October, 1891:

Water supply: North or main fork of Yuba River; abundant at all seasons.
About 43,000 "under ditch;" cultivated; no reply.
Irrigation works are under construction: Main ditch of about 20 miles; 7 miles of flume; ditch 5 by 7 and 2½ feet deep; main dam across river: base, 100 feet; top, 150; height, 26 feet; cross-section, 26 by 40; double head gate; branch ditch, 5 by 7, 2½ deep; iron piping, 1,600 feet, to convey water across a creek.
Cost of dam by contract, $8,500; flumes and ditches, $72,000.

E. A. Forbes, Yuba City (post-office), Sutter County (September 22, 1891), writes of the Brown Valley district, Yuba County:

Water supply: North Yuba River, 30,000 miner's inches.
Works: 8 miles of flume, 20 miles of main canal, 22 miles of distributing ditches; 3,300 feet of 30-inch iron pipe; one dam 26 feet high (in river), 140 feet across, 40 feet base, peeled spruce logs, inside perpendicular, 2 screw head gates, one suspension bridge.
Cost: Ditch, $1,500 per mile, average; fluming, $1 per foot; piping, $3; bridge, $6.50; dam, $7,500.
Area under ditch, 44,000 acres; under cultivation now, 3,500 acres; 35,000 can be irrigated.
Cost to user: About $3 per acre when laterals are all completed; maintenance annually, 20 to 30 cents per acre.
Cost of preparing land, $5 per acre; add irrigation cost, $8 per acre.
Annual product per acre: My estimate is, strawberries, $900 per acre; blackberries, $500; oranges, $700 to $1,000; peaches, $250 to $350; wheat, $10 to $25 or $30. The place is no good except for stock-raising, and small crops of hay without water; with water it is a bonanza.

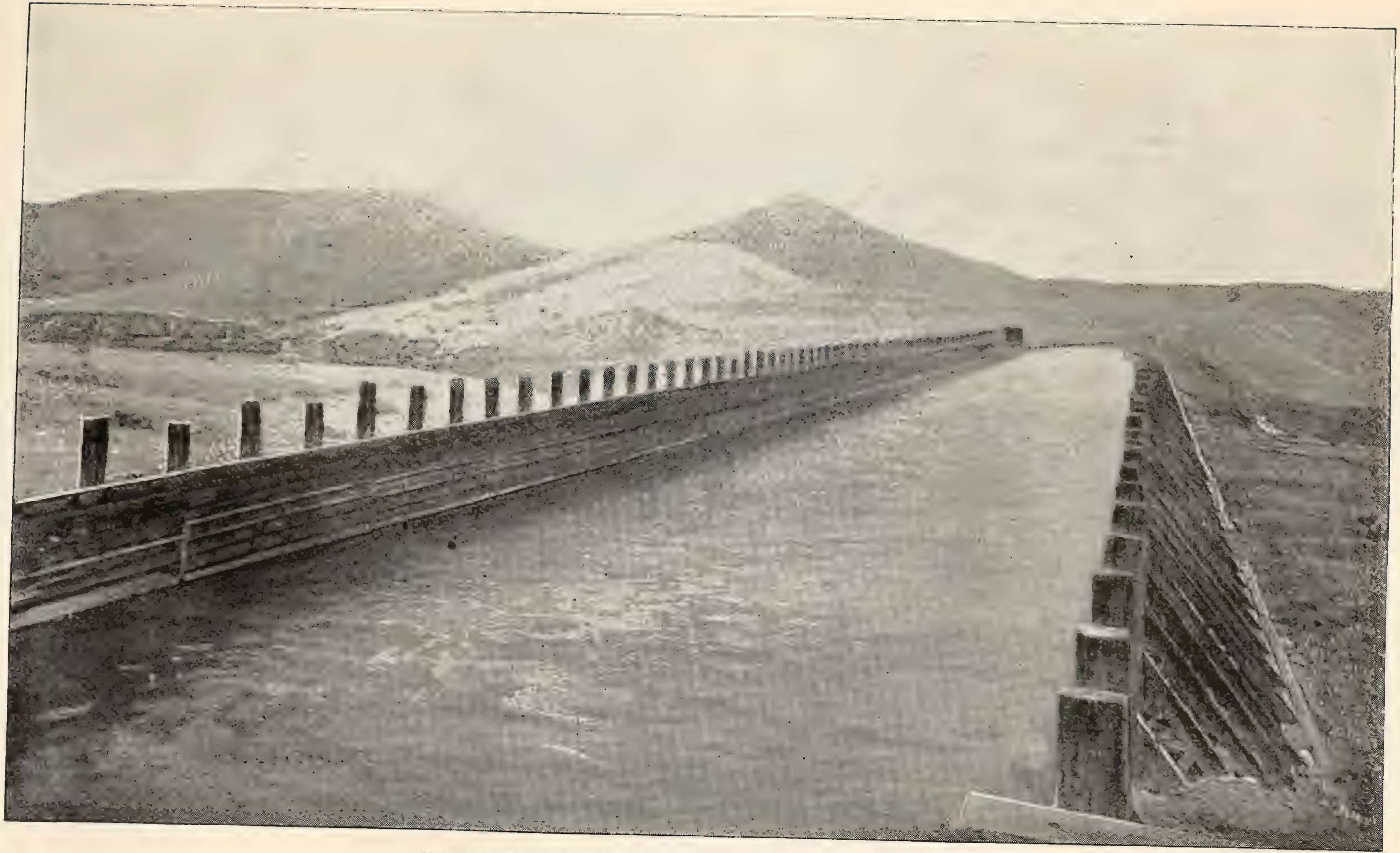
COLORADO.

Irrigation in the Centennial State continues to make serious and steady progress. It is developing in many different directions, especially in the matter of storage, but the chief growth has been, in the judgment of this office, in the way of reclaiming many comparatively small areas, in the extension and betterment of neighborhood systems of distribution, in the increase of local storage efforts, in the development of supplies from springs, undersheet, or drainage sources, of bed-rock dams, wells, artesian or otherwise, in the better knowledge or practice of economy in the use of water, in the increase of fruit culture, and generally of smaller farms and intensive cultivation. Coupled with the active and intelligent interest displayed in irrigation legislation and administration the progress of Colorado is quite satisfactory.

The fifth biennial report of the State engineer, J. P. Maxwell, for 1889–'90, is the latest authoritative statement of the administrative conditions of irrigation. The following table has been prepared therefrom:

[Condensed from State Engineer's Report, 1888–'90.]

Division.	District.	Reservoirs.	Capacity claimed.	Ditches.	Mileage.
			Cubic feet.		
No. 1	1	4	12, 687, 128	11	124
	2	12	39, 584, 332	31	236. 50
	3	11	192, 336, 426	62	351. 14
	4	8	343, 132, 944	14	176
	5	6	304, 491, 232	65	244
	6	19	369, 416, 960	67	258
	7	73	262, 955, 271	59	255. 63
	8	15	1, 648, 465, 308	132	267
	9	28	1, 929, 236, 027	22	65. 25
	23	5	3, 643, 517, 407	228	912
	46	1	1, 119, 208	88	332
	47	....	....	158	482
	64	....	....	10	98
	65	....	....	3	12
No. 2	10	30	120, 673, 455	127	508
	11	7	260, 792, 156	122	488
	12	10	226, 781, 600	48	85
	13	....	....	27	108
	14	39	1, 470, 211, 538	16	64
	15	2	....	46	88. 50
	16	2	1, 546, 632, 250	191	764
	17	3	....	9	305
	18	....	....	4	16
	19	1	13, 454, 000	29	116
	49	....	....	4	16
	66	....	....	4	8
	67	....	....	27	108
No. 3	20	....	1, 000, 000	54	216
	21	....	....	69	164. 50
	22	2	160, 000, 000	62	160
	25	1	64, 000, 000	200	312
	26	....	....	36	144
	27	3	109, 000	8	32
	35	2	20, 700	11	46
	20	....	....	3	12
No. 4	30	....	....	7	28
	32	....	....	1	4
	33	....	....	7	28



No. 1 Flume, Colorado Canal, Arkansas Valley, Colorado.

Division.	District.	Reservoirs.	Capacity claimed.	Ditches.	Mileage.
			Cubic feet.		
No. 5	28	......	......	36	......
	37	1	3, 750, 000	140	560
	38	7	2, 273, 000	43	100. 90
	39	17	27, 795, 000	13	24. 50
	40	22	501, 388, 682	74	86. 38
	41	5	24, 175, 800	70	280
	42	10	75, 551, 209	85	226. 32
	45	3	11, 200, 000	67	87
	50	......	......	3	12
	51	......	......	6	24
	52	......	......	10	40
	53	1	318, 655	19	76
	59	......	......	11	44
	60	1	266, 666	3	12
	61	2	304, 300, 000	1	4
	63	......	......	4	16
	68	......	......	1	4
No. 6	43	4	6, 802, 783	87	133. 55
	44	......	......	19	76
	54	......	......	3	12
	57	1	......	26	104
	58	2	1, 465, 120	84	336
	11. 60	360	13, 569, 903, 857	3, 267	9, 793. 17

The state engineer's report shows for 1890 a total of—

Individual ditches for which decrees of water have been issued and filed in the engineer's office, 1890	1, 673
Filed from 1887 to 1890	2, 040
Total	4, 311
Total mileage of ditches as far as constructed, 1890	11, 052. 90
Total area under ditch, 1890	4, 082. 738

But the total acreage irrigated reported by the water commissioners for thirty-four districts was only as follows for 1890:

	Acres.
In alfalfa	161, 854
In cultivated grasses	42, 592
In natural grasses	389, 430
In other crops from ditches	437, 147
In seepage water from ditches	18, 546
Total reported	1, 063, 304

No report of the orchard, small-fruit, garden, and vegetable areas within the State is given. It is certainly not less than 60,000 acres. There are many small irrigations which escape attention and are not reported because they are in sections where no appointment of water commissioners has been made. The small-area irrigation is on the increase. It is not too much, therefore, to estimate the area of irrigation in 1890 at 1,700,000 acres, and for the year 1891 an increase of 100,000 acres, or 1,800,000 irrigated and cultivated acres.

Engineer Maxwell estimates that for 1890 there were irrigated from stored water within the area of water division No. 1—that is, the valley of the South Platte—about 100,000 acres. He says (p. 17 State Engineer's Report):

> The stored waters being used in connection with that running in ditches renders it impracticable to determine accurately the acreage irrigated therefrom, but the figures are given as close approximations
>
> Colorado is, evidently, now entering upon an area of reservoir construction, the necessity for which has become apparent wherever there is a deficient water supply during the irrigating season, and as there is an element of danger connected with such improvements, all possible safeguards should be provided against such disasters as have occurred in other sections of the country within the past few years.

An important discussion is given as to the duty of water. The State engineer says (pp. 46–49:

> The waters of the eastern slope being very closely appropriated and the means of diversion provided, it is not of so much importance to determine the present duty of water for future canal development as to realize its maximum duty for the better cultivation of lands already under ditch. Whatever service water may perform at this time, we know that service can be increased by eliminating many of the sources of waste apparent on every side. The varied conditions of soil and surface preclude the possibilily of a uniform standard, but there are local causes for a diversified duty, even where the lands are not appreciably different.
>
> Water rights vested on a basis of the low duty assigned to water ten years ago have, in instances, deteriorated lands and reduced their productiveness by a surfeit in application, while on adjoining lands, through an enforced economy, a higher duty, better condition of the soil, and greater productiveness have resulted.
>
> Unskilled labor has a penalty of 25 to 50 per cent attached to it in the application of water, and unfortunately this class is too prevalent in the irrigating fields, in many cases no other being obtainable.
>
> An abundant water supply tends to carelessness in its application and consequent waste. Where liberal and old water rights are provided it is frequently the practice to turn the water upon the land and permit it to run without change or attention throughout the night, and sometimes during the day, a large volume of the water soaking into the soil without benefit to the crop.
>
> * * * * * * *
>
> The duplication of ditches is another fruitful source of waste, reducing the duty of the volume of water, as indicated by the gauging stations in the cañons.
>
> The paralleling of ditches at inconsiderable distances apart, the upper one of which could be made to answer the purposes of all with marked economy in water, as well as a large saving in capital, is also indicated as a great cause of waste.
>
> Too little attention has also been given to the proper preparation of the surface to facilitate the rapid spreading of the water. This is principally the result of too large individual ownership of land, rendering it impracticable to give close supervision and secure careful preparation of the land. The best results will be obtained from small proprietory rights in land and a consequent higher state of cultivation. The ownerships of the cultivated lands of the State should be multiplied by ten and the population increased to that extent.
>
> We are enabled to give some general results as to the service water has performed in some of the older districts of the State, for the two years last past, based upon the gaugings of the several streams at the cañons and the areas under cultivation, as reported by the water commissioners.

Tabulated statement of water duty on streams indicated for 1889 *and* 1890.

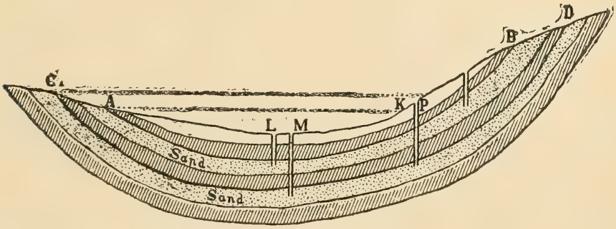
[Report of State Engineer of Colorado.]

Streams gauged.		Mean discharge from May 20 to Sept. 20, per second.	Area cultivated.	Equivalent in depth over area.	Rainfall during period.	Total depth over area.	Duty per cubic foot.
		Cubic feet.	*Acres.*	*Feet.*			*Acres.*
Cache La Poudre	1889.	735.97	139,222	1.178	.682	1.860	189.168
	1890.	770.51	139,222	1.254	.338	1.592	180.687
Big Thompson	1889.	214.53	91,037	.579	No data..	....	424.35
	1890.	425.42	89,790	1.192	No data..	....	211.06
St. Vrain	1889.	215.46	94,013	.563	.532	1.095	436.33
	1890	284.238	94,365	.739	....	....	332.69
South Boulder and Boulder Creek	1889	461.97	77,682	1.406	....	....	168.15
	1890	419.33	76,682	1.34	....	....	182.86
Bear Creek	1889.	60.40	10,173	1.46	....	....	168.42
	1890.	33.98	8,112	1.03	....	....	239.02

The review of the State, after these general statements, has been confined to an examination of certain sections showing special growth in reclamation by irrigation, with features that require particular attention, and which were personally investigated during the journey of the special agent in charge in the summer of 1891. The story of the Union Colony's "Community Ditch No. 2" is one of great interest to all who are engaged in the work of cultivation by means of irrigation and to those who are investing in canal enterprises. It illustrates what may be done by association. One of its most marked features is the almost entire absence of litigation. This fact, combined with the economy of service, makes "Community Ditch No. 2" one of the most noticeable irrigation enterprises in the United States. All the statements have been personally verified by an examination of accounts and by the testimony of those operating under the ditch. This work was carefully performed by Mr. M. A. Downing, under direction of the special agent. The San Luis Valley report illustrates the magnitude and character of large canal enterprises, as well as the remarkable development there of artesian wells and other phreatic supply. The engineering character of the Upper Arkansas Valley works are notable, and the methods of water administration are worthy of note. In addition there are summaries of information replies received by this office, as well as obtained by personal investigation.

Prof. Louis G. Carpenter, of the State Agricultural College, has during the year published an interesting report on the artesian wells of Colorado in which he gives a clear and concise account of the interesting development of such supplies. Prof. Carpenter's ability and experience adds value to his figures and deductions. He says:

> The conditions for the existence of an artesian well basin are that there should be some source of water supply higher than the location of the well, and that there should be a porous stratum which is confined by impervious strata both above and below. This strata must be continuous. In general the water should have no means of escape lower than the point where the well is, but when the distance to an outlet is considerable the friction in the intervening distance may be more than sufficient to make up for the difference in level. The pervious stratum may consist of any material which will allow water to pass through it, but most commonly it consists of sand or sandstone. The more open and porous this stratum is, the more abundant will be the flow with any given pressure. No rocks are perfectly impervious, but thickness will compensate to a great extent for a slight porosity. The confining stratum generally consists of clay or shale.



> The region where artesian wells are found is generally spoken of as an artesian basin, largely because the typical form of such a region is a genuine basin, with the rim higher than the center. A section of the Denver basin is of this form. The figure may represent an exaggerated section of such a basin, with a porous strata outcropping at B, D, C, and A. Anywhere lower than the line A K flowing wells might be expected if the strata are continuous, but as we reach K, or some point nearer B, it will be found that water comes only to the surface, and still higher it may fail to reach the surface. It is also evident that while at P flowing water will not be obtained from the upper stratum, by going deeper it may be secured, because the outcrop of the stratum which furnishes it is higher.
>
> "The figure also shows why the pressure is generally greater as the depth is greater. This fact has given rise to a popular belief that if one only goes deep enough flowing water will surely be obtained. Unless the proper conditions are present this is not true, and it is useless to expend money in that hope.
>
> "The supply of water which comes from a well, or series of wells, is never unlimited, though it may be very large, as in the wells of Dakota, or in some of those in

the San Luis Valley. Its limit is set by the amount which is supplied to or absorbed by the water-bearing stratum, from water which falls on or flows over the edges of the strata. Where the strata reach the surface at a small angle the area exposed to absorption or to rainfall is much greater, and the case is more favorable than where the angle is great. The capacity of the wells is limited by the amount these edges can absorb, or to the supply which may fall upon them. The edges may be covered by surface soil, or may be less pervious, in which case the conditions are less favorable for a large supply. If the number of wells is increased largely in any basin, there generally arise indications of a limitation of the supply in the effect of one well upon another, or on the general flow. When such a point is reached it is time that some consideration be given to the conditions, for the value of such a supply can not be overestimated. Its value becomes greater with the increase of population. When many wells are put down in a small area, the decrease, which is generally noticeable, may not indicate that the general supply is overdrawn, but that the local supply is—that is, the water flows from the wells faster than the supplying strata furnish it."

On the value of water in connection with an artesian supply Mr. Carpenter gives the price of water right per 80 acres in the older sections of Colorado as "rarely less than $1,200 * * * Such a right generally means 1.44 cubic feet per second." The cost of a water right "would be about $780 per second-foot, but based on the amount actually received it would probably be four times that." He gives an instance of the purchase of drainage water on the Cache la Poudre Canal No. 2 at the rate of $3,000 per second foot. Prof. Carpenter says:

If water has reached such value in a community not more than twenty years old, and that, too, where tropical fruits or the large returns of a more torrid climate can not be expected, it may well suggest that before many years it may pay to expend sums for the development of supplies which would not now be thought of, and it impresses the economic importance of conserving such supplies as we have and of utilizing them to the fullest extent.

One advantage in the artesian wells is in their continuous flow, as in the case of the drainage water above mentioned. In most streams of the State the water is high for a short time only during the season, and during July and August it becomes scanty, so that late crops often suffer in consequence. The surplus water of June runs to waste. Where the flow is uniform throughout the season, a duty of some three or four times that used as the basis of water rights in Colorado may be expected.

The flow from many of the wells is small, so small that the owners think it is of no use in irrigation, and therefore allow the water to run to waste.

In other countries a stream no larger than a pencil is highly prized. In Sicily, for example, water is measured by an orifice or pipe known by a term equivalent to a "goose quill." The same is the case in the Island of Madeira. Throughout Asiatic countries, and especially in China and Japan, the utmost care is taken in economizing the smallest stream. Mr. Carpenter continues:

The stream alone could effect no irrigation of consequence, but by running into a small reservoir it can be stored, and then a large head used for a short time. The greater effectiveness of a large head is well known in Colorado. In a similar way the water from many of the wells, which now runs uselessly away, could be made to perform a service which would be considerable in the aggregate. Some are already being utilized in this way to a greater or less extent, but generally without storing.

The cost of sinking generally increases more rapidly than the depth, so that except in exceptional cases, such as extremely easy boring, as in the San Luis Valley, or great supplies of water, as in Dakota, it will not pay to attempt deep wells for irrigation purposes. The temperature increases with the depth, which is an advantage if the water is to be immediately applied; but the water is also more mineralized, which is a disadvantage or not, according to the character of the solids present.

On the several basins in Colorado, the professor gives his conclusions as follows:

The wells of the Denver basin have been put down almost exclusively for domestic water. There has been comparatively little thought given to their use for irrigation; nevertheless many of the wells are irrigating areas of from 1 to 10 acres. Nearly all those in the country are used to irrigate gardens. Some are used for the raising of fish. The cost of the well, taken with the small amount of water obtained as a rule, prevents many being sunk for irrigation.

* * * * * * *

The uniform appearance of the valley (Rio Grande), as well as the conditions which have made it an artesian basin, is due to the fact that in former geological times it was an immense lake, formed by the damming of the Rio Grande by the large mass of basalt in the lower end of the valley, and which is probably also the cause of the abrupt bending of the Conejos and other rivers to the north. In consequence of the late formation, the characteristics are fairly uniform over the whole area, though there is much variability, as is to be expected, in the thickness and number of the strata. Near the ancient bed of the Rio Grande there is especially great variation; elsewhere there is great uniformity over considerable distances. The water is found everywhere, so far as learned, above the rock, which, in the western part of the basin, is comparatively near the surface, but at Alamosa is not found in the well which is 1,000 feet deep. The wells are sunk so easily and rapidly that few records are kept of the strata passed through, but the following, taken by J. M. Chritton, in T. 39 N., R. 9 E., is typical of the whole district.

Strata.	Thickness.	Depth.	Flow.
	Feet.	*Feet.*	
Dark, sandy loam	7	7	
Coarse sand and gravel	13	20	
Fine light-yellow sand	22	42	
Yellow impervious clay	18	60	
Blue clay or soft slate	98	158	
Black sand	1	159	Small flow.
Blue clay	4	163	
Fine black sand	3	166	Fine flow.
Blue clay	45	211	
Fine black sand	12	223	Flow.
Blue clay	53	276	
Black sand; flow so strong that with our pump we could not go deeper.			

The cost of the small wells flowing from 5 to 25 gallons per minute through a 2-inch pipe is as a rule from $25 to $75. Irrigation was not specially considered when wells were first sunk. Mr. Carpenter continues:

> Where the flows are large they are used to some extent, and sometimes small reservoirs have been built for storage. The 3-inch well of Espinosa, already mentioned, is said to irrigate some 100 acres of hay land. J. M. Chritton writes that he was irrigating 16 acres in 1889 from one well. L. W. Smith, a few miles west of Alamosa, irrigated 40 acres of crops, consisting of oats, wheat, barley, rye and potatoes, from two 3-inch wells, in 1889, and stated that he intended to farm 100 acres during the present season by using a reservoir of 1½ acres. Several wells in the vicinity of Espinosa furnish water for irrigation.
>
> The supply of water from the river is not yet fully used, so there is not so much inducement to consider means of using water in the quantities furnished by most of the wells, but with the closer settlement of the valley there is no doubt they will be of considerable importance in the aggregate.
>
> The water furnished by the Bucher deep well at Alamosa exceeds one cubic foot per second, and the cost was $2,700, so that, if water should reach the value it has in the older farming communities, such a well might be considered a good investment.

The necessity of knowing the limit of supply is strongly presented. The best practical test is the observation of the pressure, and that "depends principally on the height of the water level above the point where the test is made." Mr. Carpenter states of the San Luis Valley, that—

> The source of the supply for the wells is to be found at no great distance in the streams from the mountains which pour their waters into the sands of the western part of the valley, and to a lesser extent from the streams of the eastern side. These have gradually raised a delta of sand where they enter the plain higher than the basin proper and consisting of a coarser débris which has been brought down. Farther out in the valley the beds of clay begin. All of the smaller streams are entirely lost in these beds of débris, as the map shows. Of those which do not disap-

pear it would be interesting to know whether there is any marked diminution of their volume in passing over this absorbing area. The watershed of the smaller streams from the west, which entirely disappear, is some 460 square miles of the Saguache and San Luis creeks, about 1,300. The amount brought into the valley by means of these streams is unknown, but the ratio it bears to the area of the watershed will be approximately the same as in the case of the Rio Grande. The discharge of the Rio Grande, as measured at Del Norte, corresponds to a depth of 12 inches very nearly over the whole watershed. Assuming the same depth as the amount flowing off from the smaller streams, their total flow would average about 330 cubic feet per second. An unknown amount comes from the San Luis and Saguache creeks and from the mountains of the east. If we assume that this may be as much more, as seems a reasonable estimate, the total amount available would be some 600 cubic feet per second.

Taking all these sources into consideration it seems safe to conclude that while the supply will most likely exceed 600 feet per second it is not apt to reach 1,500. The average flow of the present wells in the valley may be taken as 25 gallons per minute, whence their combined flow is in the neighborhood of 110 cubic feet per second. It is probable therefore that the number of wells may be increased until the flow is six times as great, but not likely that it may become fifteen times as great. Assuming the smaller amount as the amount of water eventually available, if it were all used in irrigation it might irrigate at seventy acres to the second foot some 42,000 acres, and if used with storage three or four times as much.

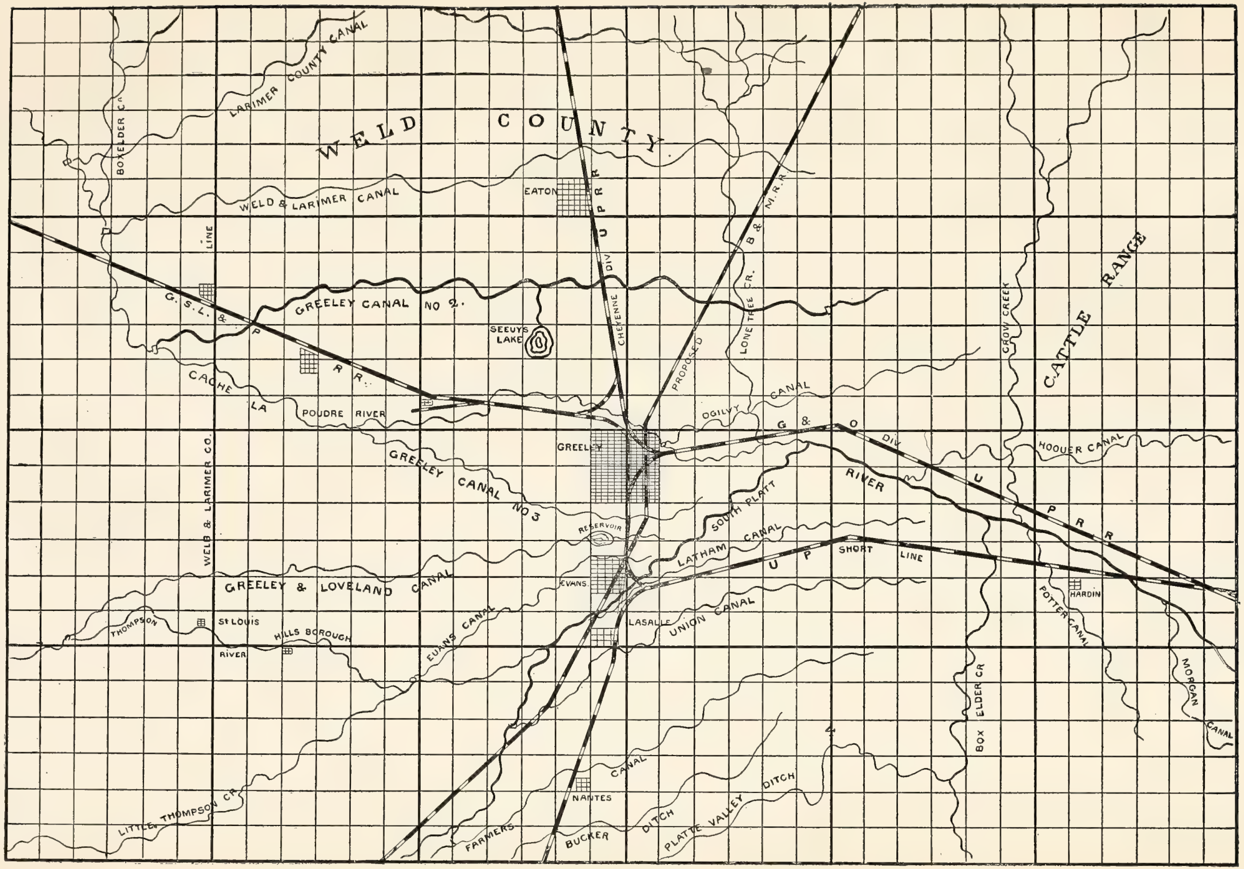
COÖPERATIVE IRRIGATION IN COLORADO.

The Union Colony of Colorado was the earliest organized effort to farm by irrigation. Before its organization there had been no irrigation in the United States worthy of the name, unless at a few points in California and among the Mormon farmers of Utah. The name "Union Colony," the suggestion of Mr. John Leavy, expresses fully the purpose of the founders. In 1870, under the leadership of N. C. Meeker, the colonists founded Greeley and coöperated to accomplish the difficult task of irrigating from one source 25,000 acres of land. Each farmer was to own his own land in fee simple, but the irrigation canal was to be the property of the community. The land selected for this experiment lies on the banks of the Cache la Poudre, which rises in the snowy range of the Rockies and after a precipitous course of 30 or 40 miles debouches on the plains, where the fall is from 10 to 15 feet to the mile. At the outset four canals, forming a system, were projected, but for various reasons all but No. 2 and No. 3, as they are now called, were abandoned. No. 2 canal is a community ditch, owned and operated by the farmers and is probably the most economically managed canal in the United States. The circular of the Union Colony promised the farmers who took lands that:

> Land is to be furnished with water for irrigation. The colony digs the ditches and each member of the colony is liable to an assessment for keeping the same in repair. It is estimated that the ditches for irrigating the lands of the colony as stated [it was then proposed to irrigate about 60,000 acres] will cost about $20,000, for which there is money in the treasury.

This promise was not redeemed by the colony, and the expense of the final construction of the ditches was far in excess of the amount originally appropriated out of the funds contributed by the colonists.

The history of No. 2 Ditch is the only part of the story of the Greeley colony that is important in this report. It takes its water out of the Cache la Poudre River, 17 miles west of Greeley. The first work was done on it in the fall of 1870 and the spring of 1871, but it was then only a small affair. As originally constructed it was 26 miles long, with a fall of 3 to 4 feet per mile, 10 feet wide on bottom for the first 5 miles, 9 feet wide for the second 5 miles, and diminished in the same proportion throughout its length. It carries about 2½ feet of



Community Ditch No. 2, with other Canals Supplying Irrigated Lands at Greeley, Colorado.

water. The cost amounted to $27,000, and only 2,000 acres were partially irrigated. The situation of the colony at the close of 1871 was very critical. Instead of four ditches and an irrigated area of 60,000 acres the farmers were confined to about 2,000 acres of partially watered land. At this time, besides the No. 2 Canal, No. 3, a small town ditch, furnished a little water. Water rights in No. 2 had been sold for 320 80-acre tracts. To meet the difficulty two assessments, amounting to 35 cents an acre in all, were levied on all lands to be watered by No. 2, which realized about $7,960. This sum was paid by the farmers themselves, independent of the liability of the colony organization. The colony, out of the funds received from the sale of its colony membership certificates, made up the balance of the cost of the first enlargement. This work was completed before the close of 1872. There are no records from which to ascertain the cost of this enlargement, but, assuming that it cost as much as either of the other two subsequent enlargements, it must have been in the neighborhood of $20,000. In 1877 the canal was enlarged for the third and last time, and from that time forward has furnished sufficient water for all the water rights, or 320 cubic feet per second.

In 1878 the organization known as the Union Colony of Colorado turned over all the rights in the canal to the farmers under it, who organized and incorporated as the "Cache la Poudre Irrigation Company," and since that date have managed the canal by a board of directors. The question of the cost of the No. 2 Ditch is much mooted, and it is only by analysis that the same can be ascertained. Union Colony expended the first cost, $27,000, out of the colony funds. To provide for the first enlargement the farmers assessed themselves 35 cents per acre, making in all $7,960. This being insufficient, Union Colony, as such, contributed $12,040 additional, making in all for that enlargement $20,000. The colony thus paid for the ditch, before its interest ceased, $39,040. The minutes of assessments since 1885, the earliest record in the office of the secretary of the Cache la Poudre Irrigation Company, are as follows:

Year.	Assessments per water right (80 acres) of—	Total amount.
1885	$20	$6,400
1886	14	4,480
1887	12	3,840
1888	9	2,880
1889	9	2,880
1890	16	5,120
1891	16	5,120
		30,720

During the seven years mentioned this would be an average annual assessment of $13.72 per water right for 80 acres, or $17\frac{15}{1000}$ cents per acre. The officers of the present company, the secretary of the colony, Henry T. West, and all the original colonists agree that the expenses for the thirteen years previous to 1885 would average no higher. Therefore up to 1885 the cost of the ditch to the farmers would be $57,075.20; cost to colony organization, $39,040; cost of maintenance since 1885 of $30,720, which would make a total cost of $126,835.20. The item of $39,040, as explained above, is $27,000, first cost of ditch, and $12,040, estimated amount contributed by the colony organization in addition to the farmers' assessment, to pay for the first enlargement. The Greeley No. 2 Ditch has therefore cost the owner of each 80-acre water right during twenty years a total of $396.36, or $4.95 per acre.

The legal name of the company now operating this canal is the Cache le Poudre Irrigation Company. The stock is divided into 2,600 shares. It is supposed that a share will irrigate 10 acres. The original 80-acre water right given the colonist represents eight shares of stock. The new company was formed in 1878, but the use of the water had all been disposed of by the Union Colony, and all that passed to the company was the administration. In the river bottom there are about 1,800 acres under this ditch that need constant drainage instead of irrigation in consequence of the soil filling up by seepage. Five years ago the North Side lateral was made, and the shares above spoken of transferred to that ditch, thus saving the water by putting it on new land. The present value of an 80-acre water right in this canal is estimated by the owners at more than $2,000, according to the latest sale made by Henry Williams, one of the original colonists. The present value of the ditch is therefore $640,000. A 40-acre tract of land with water for 80 acres was sold by the colony in 1870 for $150.

The canal is 36 miles long, 32 feet wide on bottom, slope of banks 1 to 1, and fall 3 feet to the mile. This fall is entirely too great, and the bulk of the expense of maintenance since 1878 has been caused by the expensive "checks" or board dams made necesary owing to the constant erosion of the canal bed. Of the 25,600 acres under No. 2 Ditch 6 per cent of the same, or 4,400 acres, is filled up by seepage, and the farmers, when possible, apply this water to other lands. This seepage water will come to the surface in low spots clear from the ditch to the river wherever hardpan crops out. Besides this there are several small lakes formed by turning in surplus water from the canals and seepage. The annual crop division of this 25,600 acres is approximately as follows:

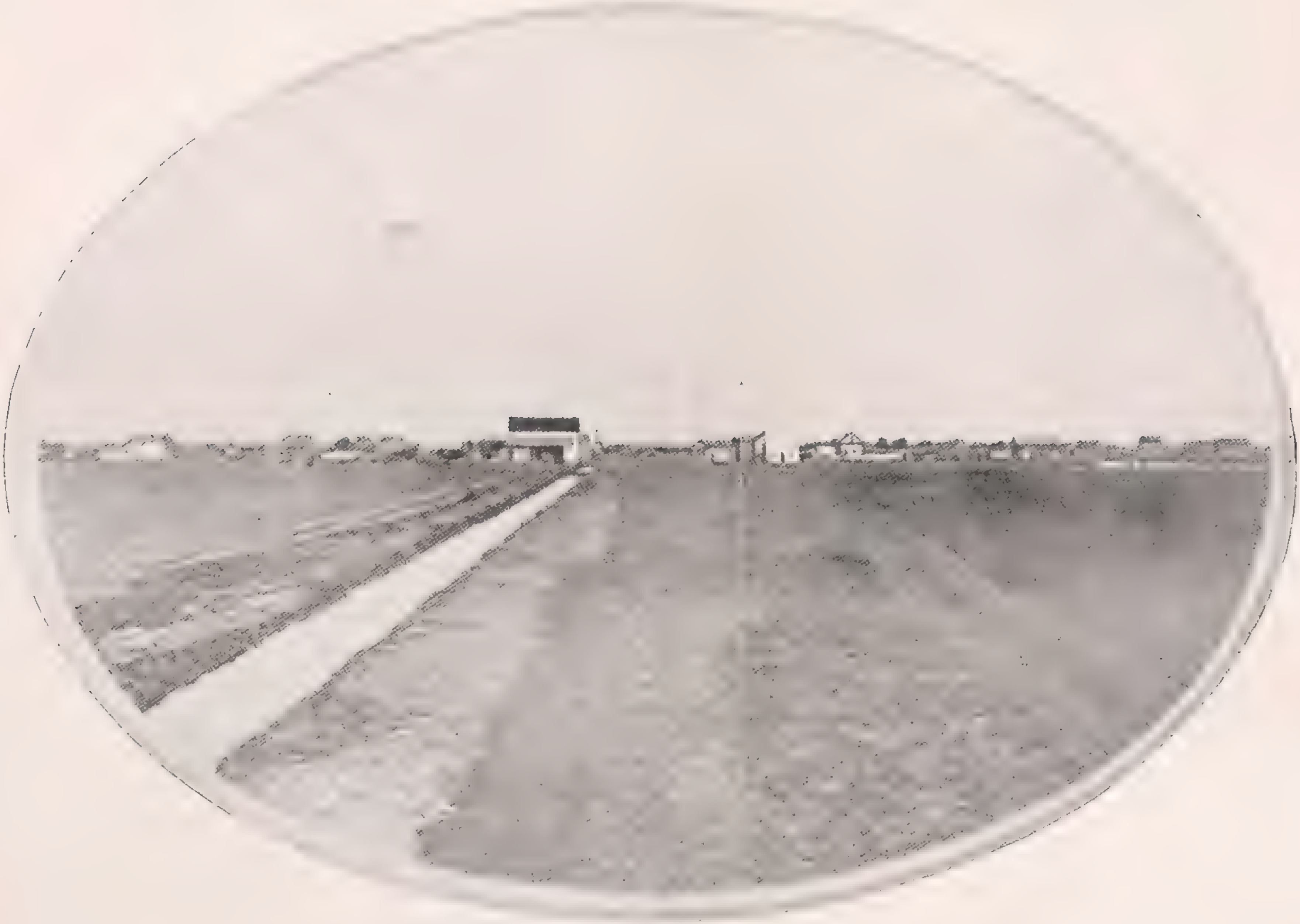
Potatoes, 5,000 acres, yielding an average of 100 sacks to the acre, 110 pounds to the sack, at an average price last year of $1.35 per hundred-weight.

Wheat, 6,000 acres, yielding 30 bushels per acre, at $1.32 per hundred-weight.

Alfalfa, 6,000 acres, yielding 3 tons per acre, at from $5 to $6 per ton.

Barley, oats, and corn, 4,000 acres, yielding 35 bushels per acre, at corn, $1.15 to $1.60; oats, $1.25 to $2; barley, $1.40 per hundred-weight, and the balance of the land is divided into vegetable and garden land. This shows an average value of product of $50.10 per acre on the staples named.

It will be interesting to contrast No. 2 Canal, as built by the Union Colony, with the Larimer and Weld Canal, built by a corporation, which is practically along the line of No. 1 Canal, projected by the colonists, but never taken out. Col. E. S. Nettleton was the engineer of both. The ditch built by the Union Colony, and since maintained by the farmers, has cost for construction and maintenance, during twenty years, $126,835.20, or $3,459 per mile. The Larimer and Weld cost $3,000 per mile for original construction, or $156,000 as first cost of its 52 miles of length. A water right in the latter ditch sold for $15 per acre, or $1,400 for an 80-acre tract. The annual rental is $10 for 80 acres, or 12½ cents per acre. If the Larimer and Weld Canal had been in use for twenty years the expenses for water to an irrigator would have been $1,600; that is, $20 per acre, or $1 per acre per year. Under No. 2 it has been shown that the expense of building and maintaining a ditch for twenty years is $396.36 per annum for 80 acres,



First Irrigation Colony in Arid America View of Greeley, Colorado, 1870

or $4.95 per acre, or 24¾ cents yearly per acre. This sum includes cost of building, enlarging, improving, and maintaining. The Larimer and Weld Canal is 28 feet on bottom, 6 feet deep, and 1½ to 1 slope of banks, making the canal 46 feet wide at the water line. When first constructed the work was better than that of No. 2, but the enlargement and repairs of the latter have made it at least the equal of the Larimer and Weld.

Another feature to be considered is that there has been no litigation of any consequence under the community ditch, while under the Weld and Larimer it has been frequent. Law proceedings on No. 2 have only been of a character designed to settle questions of appropriation. In June, 1891, there was an important decision affecting the corporation canal. The water contracts with the users of its water provide that the corporation shall not attempt to sell water for use in excess of its appropriation, and that the canal shall be turned over to the irrigators when all the rights are sold. The canal is only entitled to the surplus flow of the Cache la Poudre after No. 2 and No. 3 have been satisfied. In dry seasons it is alleged, therefore, that there is not sufficient water to supply the Larimer and Weld irrigators, and therefore the people sought to enjoin the company from selling any further rights based on the supply in sight, setting forth that there was not water enough for the present users. The court held that the corporation could sell water rights up to the full carrying capacity of the canal, and that the supply could not be taken into consideration as a basis of estimating the number of water rights that might be sold under the restrictive clause of the contract. Among themselves owners in No. 2 have had no litigation.

On No. 2 ditch, where each water right is entitled to one three hundred-twentieth part of the flow of the ditch, such litigation is impossible; but the irrigators having the right to determine where and when their water shall be delivered, a custom has grown up by which two or three water-right owners will consolidate their supply during dry seasons and use the combined flow in rotation, thus affording ample water to the users for rapid irrigation during the dryest seasons.

No. 3 canal, projected by Union Colony, was begun in 1870, and completed by three enlargements in 1871, 1872, 1873. The original cost was $6,333, but the enlargements, dams, improvements, and maintenance during the past twenty years, have increased the cost to about $25. Its water is used for the irrigation of the city of Greeley, and surrounding gardens. No large tracts are cultivated under it. An original colony certificate, costing $150, entitled the holder to water from this ditch for his house lot and a piece of ground not to exceed 10 acres. It is still owned by the irrigators and is run similarly to No. 2. The great fault in the early construction of these canals was the persistent attempt to keep the canals "in the ground." They zigzagged along the notched bluffs in sharp angles and all fluming and filling was avoided. The fall of 3 to 4 feet per mile was also great. Two thirds of the expense of maintaining and improving these canals has gone to straighten the channels and check the too rapid flow of water in order to save the banks.

TESTIMONY OF IRRIGATIONISTS.

An illustration of the first irrigation is to be seen in the experience of Henry Devotea, an original colonist, who states that:

> I came to Greeley with $2,000 and lost it in three years because I did not know how to run my ditches. I tried to do it by my eye, and to get my water up hill. Some of the men in those days tried to run water across a swag without diking. After

this experience I bought a level and ran my ditches properly. A good deal of conceit was taken out of me by that three years' experience. I afterwards learned it was a great deal better to have a proper survey made. My best crop of wheat has been 3,200 bushels from 100 acres, and my lowest average about 15 bushels per acre. The reason of that low yield was that I planted wheat after wheat for several years; this depleted the land. Crops must be alternated to get good yields. Alfalfa always improves land, acting as a fertilizer and breaking the subsoil. My best yield of potatoes was 250 bushels or 137 sacks per acre, but I have gone as low as 75 bushels per acre. I kept the average of my crop from 1873 to 1880; during that time I had but one total failure from causes I have described. The average yield was 20½ bushels of wheat to the acre. In good years it will run 27 and 30 bushels. It must be remembered in making these averages that I had some old wheat land in every crop, and that runs the figures down. When the crops are rotated the average should be 30 bushels.

When I first came here we had to go 130 feet to get 3 feet of water in a well. Now I have a well 51 feet deep with 30 feet of water. We strike sandstone and slight seams of coal, but the water will stand on the average at 10 feet from the surface. The water level is now within 5 feet of the surface in many places, and in some low spots during irrigating season it will come within 10 inches of the surface. My crop for 1890, minus seed, was sold for $4,500, costing to raise $800; my 100 acres returned me, then, a net profit of $37 per acre.

Mr. Devotea lives under community ditch No. 2, and was one of the constructors thereof.

Dr. Gulemus Law, a gentleman who has given much study to irrigation in and around Greeley, said that the early mistake in Community Ditch No. 2, aside from its want of capacity to carry water, was its crooked course, and consequently it cut out on one side and silted on the other at every turn. But, in a very few years practical experience taught that we could get a great deal more water through a straight ditch than a crooked one; that it was better to go through a ridge than around it, and to dike across a depression. Another fault was that the ditch was constructed at too great a slope per mile. A ditch of 3 or 4 feet per mile will cut. Two or 2½ feet is ample, and the ditch should be of sufficient size to get the benefit of the pressure of the water. The grade should not vary because if it is greater at one point than another it will cut and silt. If it is relatively straight and of an even grade and made smooth one will not have much trouble with silting; but if it is 2½ feet in one place and 4 feet in another it will cut and silt.

Land to be valuable for agricultural purposes must have a substantial subsoil under it. Sand and gravel substratum requires an enormous quantity of water to irrigate.

Dr. Law was of opinion that if the land around Greeley was properly prepared and sufficient seed used, the yield would be increased 50 per cent; at present the plowing was too shallow. Every foot of land intended for potatoes should be subsoiled in order to get best results. And the reason that potatoes do so well on alfalfa land is simply that the subsoil is thoroughly broken by alfalfa roots. An experiment on a square rod of land properly prepared for potatoes yielded at the rate of 578 bushels per acre.

E. H. Benton, a very successful horticulturist, under the No. 2 canal, asserts that there is a strip of country running 20 miles east of the mountains and 150 miles along the range not favorable to fruit, because there are a great many still days, during which the weather will get quite warm as early as February or March, and then turn suddenly cold after the sap has started. The soil is, however, good for apples and plums. If laths were woven together with wire and placed around the tree in the shape of a box, this would be overcome.

His plan is to grow low crops, such as beans, cucumbers, beets, squashes, melons, and orchards, and then mulch the trees, and do it with manure so that the frost shall not touch the roots, and leave that on until the 1st of May. Raspberries and strawberries in the orchard have a very good effect upon the trees.

Another thing is to irrigate as late as possible, into November, even if the water freezes in the ditches; then mulch to prevent frost. Last year he raised 75 sacks of potatoes in his orchard. Cabbage would do well, but no grain should be put in under any circumstances. The trees should be deeply set, about 6 inches deeper than in the nursery. An important essential in tree planting is that every root should be trimmed smooth, so that when they are planted new roots will spring out immediately. If you put a tree in with mangled and split roots none will start. It is a *sine qua non* that every root should be trimmed with a knife. Alfalfa is the crowned king in this region; a crop of it turned under will do more for the land than any other fertilizer. The Ben Davis is the best apple for this region. The Wolbridge and Wealthy also do well.

M. J. HOGARTY came with the colony, and thinks the duty of water has doubled. On large farms one-half an inch will do what an inch would hardly do formerly, but a man must have the opportunity to practice economy. For instance, an 80-acre water right is supposed to be a cubic foot per second, but half that amount is now sufficient provided there is no waste.

Last year his crop was:

Thirty acres of potatoes at 75 sacks to the acre, at $1.40 per sack	$3,370.00
Fifty acres of wheat averaged 41 bushels, at $1.33 per cwt	1,635.90
	5,005.90

an average from two staples of a little over $62.50 per acre gross at an expense as follows:

Water right	$16.00
Hired help (one man for seven months and board)	315.00
Threshing (5 cents per bushel)	102.50
Taxes	55.00
Sacks and twine	155.00
Three horses at 50 cents per day	175.00
	818.50

The total expense of farming on irrigated land is therefore only slightly over $10 per acre. The cost of application of the water is included in the cost of hired labor. The system that offers $50 net profit from potato and wheat land should be carefully studied by every farmer.

C. O. JENNINGS in 1887 paid $37.50 per acre for 80 acres. He has 25 acres in potatoes, 35 acres in wheat, 8 in alfalfa, and about 12 in trees.

Last year's crop was 325 sacks of wheat, worth $1.46 per sack; 1,200 sacks of potatoes at $1.60 per sack; and 24 tons of alfalfa, which he fed to stock. The return therefore from two field crops, 60 acres, was $2,394.50, or an average of $39.90 per acre.

His estimate of cost on a 6-acre tract is as follows:

Wheat:	
Putting in	$3.50
Price of seed	5.40
Irrigating twice	4.00
Cutting	7.50
Stacking	2.50
Threshing	10.02
	32.92
Cost per acre	5.48

Potatoes:	
Breaking (not alfalfa)	$9.00
Seed	27.00
Irrigating (three times)	6.00
Sacking, digging, and hauling, at the rate of 50 sacks per acre, at 25 cents per sack	81.00
	123.00
Cost per acre	20.50

He has five very thrifty cherry trees, but has never sold any fruit.

D. H. **Gale** farms sec. 9, R. 65, T. 6. On the east side of his farm in Lone Tree Creek there is enough seepage water flowing to irrigate 80 acres. Previous to the introduction of irrigation this creek was dry except in flood time. Six miles above his place where it is too high for seepage there is no water yet.

At Fort Collins the Cache la Poudre will be dry, and 26 miles below that place there will be water enough to fill a ditch carrying 25 cubic feet per second, the water all coming from seepage.

In this connection, Mr. J. C. Swann, who bored a well on ex-Gov. Eaton's place, half a mile north of Eaton and about 9 miles north of Greeley, on N. E. ¼ of sec. 36, R. 66, T. 7, stated that at 23 feet below the surface is a stratum of gravel 65 feet thick, of which one-half the cubic contents is water. An actual test shows that a cubic foot of the stratum yields one-half a cubic foot of water. Before the construction of the Larimer and Weld canal this gravel was dry.

Mr. Gale continuing said that on his place exclusive of stock he raised 300 acres of alfalfa, 45 acres of potatoes, 93 acres of wheat, and 30 acres of oats. His expense of cultivation was about $3,000 and he cleared gross $11,000. The first cutting of 25 acres of alfalfa measured 90 tons in the stack. He has eight water rights from Larimer and Weld.

H. C. **Watson**, president of the Greeley Mercantile Company, gave the following statistics of crop shipments during 1890:

> Two thousand five hundred carloads of potatoes, averaging 400 bushels to the car, making 1,000,000 bushels, were shipped from this depot. This crop was raised under No. 2, Larimer and Weld and Loveland and Greeley ditches.
>
> My books show an average of 25 bushels of wheat to the acre. One hundred and fifty carloads of cabbage were shipped, at an average price of 60 cents per cwt. Two acres of cabbage on the Loveland and Greeley ditch sold for $325.92. This was not in a garden. Had it been under garden culture the yield would have been from 20 to 40 per cent higher.
>
> Mr. Solomon, of Denver, rented, for a proportionate share of the crop, 160 acres, of which 110 acres were cultivated. His crop rent was $693, representing one-third of the corn and one-fourth of the potatoes. This was a small crop.

John Leavy is a horticulturist, and selected an acre tract as his allotment from the Union Colony, asserting that "1 acre of ground is all a man can properly cultivate as a gardener."

The open-ditch system is the best for garden irrigation; flooding is bad for it puddles the land. The great trouble with most irrigation is the use of too much water; one-fourth the amount used in many instances judiciously applied would produce better results. Irrigation is best practiced under intense sunshine.

The rule should be to water thoroughly, *when you do irrigate*, but do so as seldom as possible because water lowers the temperature. A little personal experience is the only guide when to apply water.

In 1885, a cauliflower raised on Leavy's place, took the prize at Peter Henderson's exhibition. It weighed 11¾ pounds, when trimmed. He also exhibited another of 10½ pounds. Cauliflower should average 75 per cent of the crop weight of cabbage. A piece of ground that will produce 40,000 pounds of cabbage should yield 30,000 pounds of trimmed cauliflower. The Erford variety seems to prosper best in this locality.

Celery requires a still higher cultivation than any of the above, but we can raise here and in similar climates in the arid region as fine celery as anywhere on earth. It is essentially an aquatic or marsh plant, and about the only one you can not injure by excessive irrigation, and a very safe crop for the inexperienced irrigator. It wants plenty of water. The best method is a modified form of the old system of drainage.

Garden by Irrigation, Greeley, Colorado, 1890.

An open shallow drain, 5 inches deep, is first constructed on the level on which is put a coat of well fermented manure to the depth of 2 inches. This manure should be thoroughly incorporated with the soil, and then you place your plants out at the usual distance apart, which is perhaps from 6 to 7 inches. Then you have only a trench of 3 inches, which gives you the advantage of—

(1) Flowing plenty of water on it.
(2) Excessive irrigation does not injure it as it is a marsh plant.
(3) It facilitates "earthing up."
(4) By the month of September the celery roots are 2 feet out from the stalk.

By this modified trench system with the plants set out on the single-row plan which is best adapted for horse culture, 18,000 to 20,000 heads of matured celery should be grown. The rows should be 4 feet apart, and the plants in any single row not to exceed 6 inches.

Beets of the mangel-wurzel variety thrive here very well and should yield from 20 to 30 tons per acre. Onions should be raised by transplanting, and the ground should not be prepared but a day or two before you are going to plant. Over 1,500 bushels and often as high as 2,000 bushels can be raised by that plan and a proper attention to irrigation.

In all crops it is not broad acreage, but labor, that tells upon the yield. The experienced cultivator will get more out of his garden than the broadcast farmer. Peas and beans do remarkably well and 30 bushels to the acre is the average here for the white beans. Radishes and all the root crops will do well. Strawberries should be irrigated through the rows, and should yield according to the cultivation from 2,000 to 5,000 quarts.

At a meeting of the board of directors of the Cache la Poudre Irrigation Company, at which were present S. A. Bradfield, H. M. Williams, J. S. Newell, O. H. Adams, Henry Devotea, and George M. Jacobs, the following statistics of expenses on an 80-acre tract were given as the agreement of all after discussion:

Hired help on an 80-acre tract	$320.00
Potatoes cost per sack	.20
Threshing	.05
Water tax main ditch, 1891	16.00
Lateral tax	12.00

Per acre yield under No. 2.—Forty-five thousand pounds of cabbage per acre have been raised by unskilled men on bottom lands, around Greeley, but any man who raises less than 45,000 to 55,000 pounds of cabbage is no gardener.

PAYMENTS MADE BY ORIGINAL COLONISTS.

Each of the Union colonists paid $150 to the colony funds, $5 of which was in the nature of an initiation fee, intended to cover the expenses of the locating committee. For this payment of $150 each individual was entitled to a selection of land as laid out by the officers of the colony.

1. A block, or a 5-acre lot immediately adjoining the town, with water in perpetuity.

2. A 10-acre tract a little farther away, or a 20-acre tract still farther away, or 40 acres at the extreme limit of the colony. The latter was the largest amount of land, with water, that the colony gave in satisfaction of a certificate. Those who desired larger amounts of land availed themselves of the contract made by the Union Colony with the Denver Pacific Railway and Telegraph Company, and their lands were commonly called railroad lands, or they filed on Government lands under the

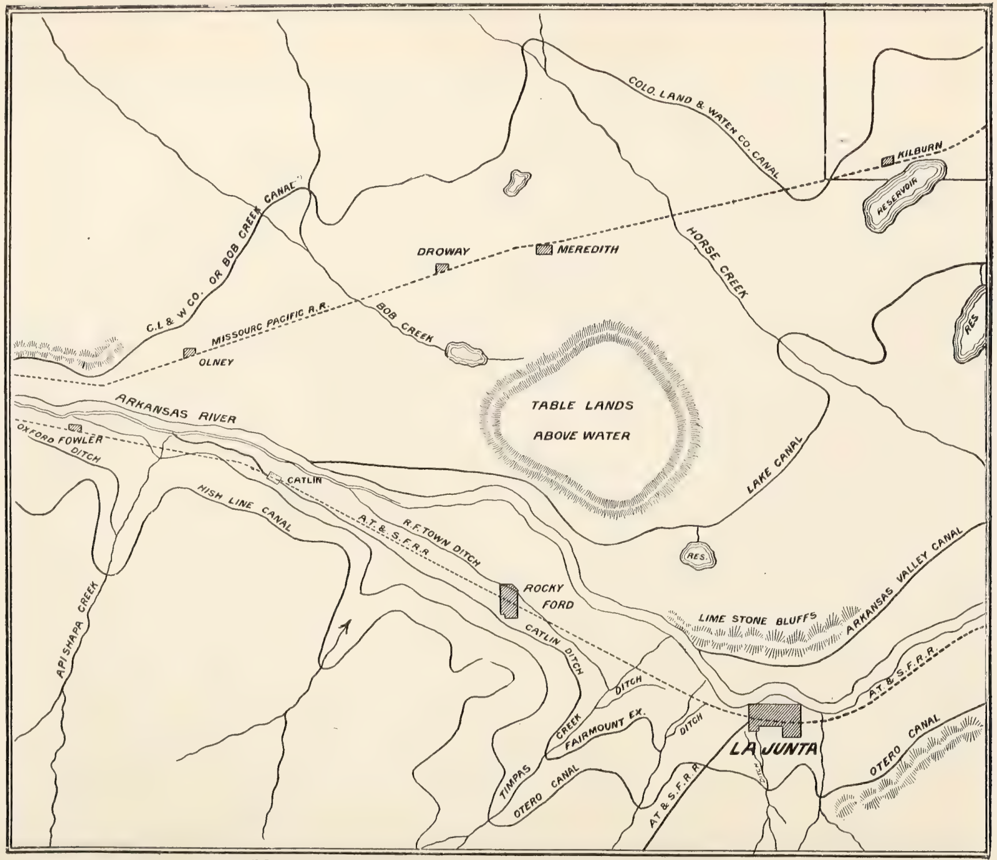
homestead or preëmption laws. To the latter class the Union Colony granted the right of water for 80 acres of land, inclusive of the land taken from the colony.

THE PHREATIC SUPPLY.

The first well in Greeley was dug at the intersection of main and Monroe streets, and water was struck at 22 or 23 feet in a gravel stratum. The second well was dug by Henry T. West, on a lot in the second block to the south, and water obtained at 25 feet. In each case there was about 3 feet of water. After the irrigation season of 1871, in the fall, instead of 3 feet of water there was 12 feet in both wells, and the water had become hard. For ten years past the water has not been potable, but has increased in depth to 19 feet. In connection with this fact, eight or nine years ago the cellars in the western and souhwestern parts of the city began to fill with water, necessitating the building of a drainage sewer along the main street. It is an open-jointed pipe-sewer about 2,000 feet long, with brick chambers for manholes, carrying 400 feet. On the 10th day of May, 1891, when this sewer was examined by the agent of the Department, there was more than sufficient water running to afford a water right for 80 acres, or about a cubit foot per second.

J. C. Swann, of Swann Bros., artesian-well borers, states that—

> The record of the Loveland well at Loveland is 30 feet of surface formation above bed rock, composed principally of gravel filled with water. The bed rock is blue slate and sandstone, the slate of great thickness and the sandstone less. At 150 feet we found a vein of brackish water in sandstone which rises to within 60 feet of the surface. Below that no water was encountered until the depth of 1,365 feet. At this point the true artesian stratum is reached. It is a close-jointed sandstone, 30 feet thick. Below it no further sandstone is reached until the 1,600-foot level, when there is another strata of close-grained sandstone 5 feet thick, containing petroleum in small quantities.
>
> Below this point, 2,400 feet below the surface, it is sandy shale devoid of water.
>
> The test-well drilled in Lincoln Park, Greeley, to a total depth of 2,140 feet, is about as follows:
>
> 32 feet soil and gravel to the first bed rock, the lower 24 feet of this stratum being filled with sheet water in about the proportion of one-half gravel to one-half water. Before irrigation the bed was dry to a depth of 27 feet. This gravel bed is universal in the valleys of the Poudre and South Platte, varying from 1 to 5 or 6 miles wide in most places to 10 miles at the greatest width at a point near Stirling.
>
> On the South Platte, at any point north of Denver to Stirling, Colo., it is a fair estimate to say that the saturated gravel will average 40 feet deep, and throughout the entire distance would not be less than 3½ miles wide. This body of gravel has always been saturated. It is a fair presumption to say that this represents a lake of water having an average depth of 20 feet and covering a territory of the dimensions above named, or 462 square miles. The source of this supply is the water that sinks from the surface flow of the South Platte.
>
> The same is true of the Poudre Valley within the limits of its extent. This valley is one continuous bed of shale to a depth of 1,165 feet, overlaid with soil and gravel, and with a substratum of 30 feet of close-grained gray sandstone, the source of artesian water; but the flow only amounted in the test well at Lincoln Park to 35 gallons per hour, which has now entirely ceased, and pumping has been resorted to on this and other wells. Below that to a depth of 2,140 feet shale is encountered all the way devoid of water. This is the deepest drilling in the Poudre Valley. Six other wells have been drilled to the water-bearing stratum in Greeley. There are nine wells, all told, in this basin, of which the one at Loveland and the one at Evans still continue to flow, but even they are not true hydrostatic flows.
>
> In surface irrigation for general field crops there is no doubt but that it requires six times as much water in spreading it over the land as the wants of the crops require. This is true in a general way of all field crops except corn and potatoes.
>
> We have but three calendar months here free from frost—June, July, and August. From the time frost ceases in May until it returns in September will be about one hundred and twenty days. Therefore what seems to be our misfortune, namely, our aridity and our intense sunshine, is all that makes this country inhabitable. Our cereals and other crops are largely composed of carbon, to produce a pound of which, in the shape of a growing plant, calls for the expenditure of heat energy sufficient



THE CANALS OF OTERO COUNTY, COLORADO.
Illustration of the progress of irrigation in the Upper Arkansas Valley.

to raise the temperature of 14,500 pounds of water 1° F. scale. The intensity of our sunshine and the almost constantly cloudless condition of our skies enables growing crops to be matured in much less time than in a humid climate. This is the explanation of our growing and maturing general crops here at all, and the explanation of the value of irrigation in an arid climate over farming in a humid climate. My own opinion is that materially better methods of distribution will come into play, and that water will continue to increase its value as an economic factor until it will never be wasted as now in Seeleys Lake and elsewhere in this region; but that combined efforts will more and more increase the duty of water even to the adoption of a system somewhat similar to the Paris street-sprinkling plan.

Irrigation as now practiced is crude, and the waste of water enormous, but its scarcity and its constantly increasing value will lead to better conservation. The general use of perforated pipes will probably be the first step.

IN THE ARKANSAS VALLEY.

In illustration of the lessons this work of coöperative farmers have afforded to irrigation organizers in Colorado, the following account of a commercial enterprise will be read with interest:

The Colorado Land and Water Company are engaged on works that promise the reclamation of a large proportion of the Arkansas River Valley and plains lying east of Pueblo. Already a considerable acreage is under high cultivation, and the special fruit and vegetable crops that are raised at Rocky Ford and other points along the line of these canals have become quite famous for quantity and quality.

The enterprise has attracted investigation, not only because of its magnitude and the success obtained in opening a large area to cultivation, but because of construction characteristics, especially by way of open plains reservoirs. These are more numerous than on any other canal system in the State, and, as a result, the storage facilities obtained are very large.

Reservoir No. 1 covers, when filled, nearly 700 acres, and 16 feet can be drawn off. Reservoir No. 2, when filled, covers 2,100 acres, and 14 feet can be drawn off. Reservoir No. 3, when filled, covers 21,000 acres, and 40 feet can be drawn off. Reservoir No. 4, when filled, covers 5,600 acres, and 22 feet can be drawn off. The first two of these reservoirs are in Otero County, and Nos. 3 and 4 in Kiowa County. The total acreage covered is 29,500, and the average depth is over 20 feet.

The original survey of this canal was made about 1885 by H. R. Holbrook, C. E., of Pueblo, for a company called the Pueblo Land and Canal Company. This survey covered the ground occupied by the present canal, and located the large reservoirs at the eastern terminus of the present ditch. E. S. Nettleton (chief engineer of the Artesian and Underflow Investigation), after examination, stated that the largest reservoir would irrigate, when filled, 200,000 acres of land.

The Colorado Land and Canal Company was afterwards organized by Colorado Springs parties, who re-surveyed the line of canal and did some construction work in April, 1889. Early in June, 1890, this present company bought out the interests of the Colorado Springs people, and continued the work of construction actively, completing the canal to its present terminus at the crossing of the Missouri Pacific Railroad, east of Horse Creek, a distance of about 74 miles.

The headgate is on the north side of the Arkansas River in the NE. ¼ NE. ¼, sec. 10, T. 21 S., R. 62 W., in Pueblo County, Colo., 426 feet east from the section line. The canal is 30 feet wide on the bottom, not less than 8 feet deep, with side slope of 1 to 1 foot and a fall of .056 feet per mile, except for the first and second miles, which are 4.22 for the first and 2.64 for second. The computed carrying capacity with 7 feet of water running is 756.28 cubic feet per second. At the intersection of

Boom Creek there is a waste way 40 feet wide constructed to the river. The first flume, 700 feet long, is 12 miles from the headgate over Krammer Creek. The creek bed is shifting sand, ordinarily dry on the surface but yet draining 50 miles of country. This flume affords passage for storm water under the canal.

It rests on oak-pile bents or supports for the flume, 16 feet apart, 7 and 8 piles to the bent, capped with 12 by 12-inch timbers and braced against lateral pressure of wind or flood water. The floor joists are 6 by 12 inches and 16 feet long, set at 2½ feet from center to center, covered with 2-inch plank laid transverse to joints. The side posts of the flume are 6 by 8 inches, 9 feet long, well braced against heavy timbers resting on the projecting ends of the bents, and are lined inside with 2-inch planks to a height of 8 feet.

Automatic waste gates are set in the south side of the flume, of a combined width of 32 feet; shut-off gates are also put across the flume just below the waste gates, by which the water can be entirely directed from canal in case of accident to banks. Two hundred and fifty thousand feet of Mexican timber have been used.

The inside width of head gates is 38 feet 5 inches, and inside length 73 feet 6 inches. There are twelve check gates averaging about 2 feet 7 inches, and 8 feet 4 inches high. In connection with these head gates there is also a waste or spill way with thirteen gates. These are a little wider and the same height as the check gates, and in connection with the waste way there are gates that can be opened from the north to carry off the flood waters of Haines Creek at that point. These gates, opening to the north, are six in number and are about 2 feet wide and 4 feet high, and have proven a great success. The controlling gates are raised 12 inches above the canal floor so as to allow the sand to scour out through the waste gates. This feature, combined with fall for the first mile of 4.22 feet, keeps the channel well scoured out.

The canal is divided into 100-feet stations and all flumes are constructed substantially as in the foregoing description. This company completed the canal under contract with the State of Colorado, from which it has bought and leased the alternate half sections of State land lying under the line of the canal. Title has so far been obtained, by work done, to 72,000 acres, that is 36,000 acres purchased and 36,000 acres leased. Under this contract the State retains ownership to one-half of the entire tract of land, which is leased to this company at a nominal figure, and will eventually realize the difference between the value of raw and cultivated land. The company is compelled to apply water on all of this leased land in order to make good their title and the State agrees that in any future lease or sale to other parties the water shall be treated as an improvement to the land, the same as fencing, building, or other improvements are, as provided for by law. In disposing of the purchased lands an equal amount of leased land is given each purchaser at a very small rental and the improvements made thereon are to be purchased by any subsequent lessee or vendee at their full value.

The intention is to run the canal all the year round when safe to do so, storing the water of the Arkansas River in the basins. This can be done in large canals, as the water continues to run under the ice without disturbing the banks. The unused waters of the Arkansas River flowing to waste in the fall, winter, and spring, will be stored when not needed for irrigation, and also all flood water. The prevailing rule is for canals to "shut down" in winter, so as to prevent breaks. In this way the waters of the area served are of course allowed to run to waste.

The Arkansas system proposes the opposite course. There is very little artificial embankment on our reservoirs, and the cost not much compared with the magnitude of the scheme and the results obtained. The cost of the entire canal together with land purchased and leased has been:

Cost of canal now built	$376,000
Cost of reservoirs and extension of canal into them with necessary laterals cut from the canal, estimated at	124,000
	500,000
Cost of 36,000 acres of purchased land	90,000
Cost of 36,000 acres of leased land	10,000
	600,000

The canals with its resevoirs, will fully irrigate 300,000 acres, which figure, it is claimed, by economy of service, may be materially increased.

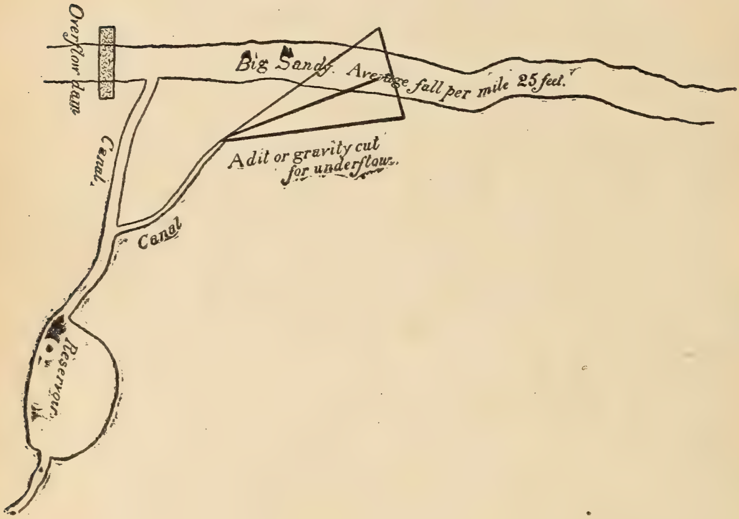
The service of water is generally 1.44 cubic feet per second for 80 acres. This corporation has adopted 1.08 cubic feet, which, according to the best authorities, is sufficient for Colorado lands; in fact the tendency is to restrict the amount to 1 cubic foot for 80 acres.

The use of water is restricted to 100 days' continuous delivery or the irrigation season, which is fixed by the contracts to begin April 15 and end September 30. This service is an innovation, as the rule has been to fix the period of continuous delivery "as during the irrigation season," which under Colorado statutes begins April 1 and ends November 1. The motive in the decrease of forty-five days is to prevent waste. Practically the delivery is not continuous, as no man can use water every day. In northern Colorado, where the finest grapes have been raised, the crop seems to be in direct ratio to the scarcity of water. That a much less amount of water is required has been established by experience there so that the secret of success is using the water at the proper time. The ditch and reservoir system, while under the same management, are under different companies and any one desirous can exchange his water; for instance if a man uses but sixty of his one hundred days he may run his unused water into the reservoirs and thus get credit for water outside of the irrigation season. A water right costs $10 per acre or $800 per 80-acre water right, and an annual rental never to exceed $16 per water right for maintenance and repairs, or 20 cents per acre per annum. This is about the rate on community ditch, No. 2, at Greeley, and is based upon the experience of that enterprise.

Besides the Colorado Land and Water Company Canal, also known as the Bob Creek Canal, the Lake and the Great Arkansas Valley canals take water out of the Arkansas River on the north. The Highline, Otero, and Catlin canals and the Oxford and Rocky Ford ditches distribute the water on the south. The staple crops are wheat, corn, and alfalfa. There is a considerable area in orange orchards, and acres are devoted to melons, yielding large returns. The area of reclaimed land in Colorado, while being sensibly increased by the completion of such large canals as the Otero and Colorado, is making equal, if not so apparent, progress in the reclamation of small areas; on the Big Sandy, for instance.

During February and March, 1890, there was a dam thrown across Big Sandy Creek, on the Kansas division of the Union Pacific Railway, near Lake station, about 93 miles from Denver. The structure was 1,100 feet long, 72 feet wide on the bottom, 16 feet on top, and 12 feet high. A ditch therefrom was 6 feet deep and 60 feet wide on the bottom, carrying water to a reservoir about 1 mile distant. The dam broke away on the 11th day of August, 1890, but will be repaired under better construction. The volume of water during that flood was 5 feet deep and 640 feet wide. The reservoir will contain 968 acres, at an average depth of 12 feet, and will irrigate from flood water alone 17,500 acres of land. The underflow may also be utilized to irrigate as much more. The water-bearing sand, from which the underflow is gathered at no point more than 12 feet below the surface, is 1½ miles wide and of unknown depth.

The general plan of the works is as follows:


Overflow dam
Big Sandy. Average fall per mile 25 feet.
Adit or gravity cut for underflow.
Canal.
Canal
Reservoir.

The Howard Ditch, on Box Elder Creek, about 35 miles east of Denver, cost $400, develops 204 cubic inches of water, or more than 6 cubic feet per second. Over 300 acres are now cultivated from it. If properly developed 15,000 acres could be irrigated from this source.

The Gusbueck Ditch and Reservoir, 70 miles southeast of Denver, in Elbert County, cost $600, it develops 200 cubic inches of water, and irrigates 300 acres of land. At Agate, on the Kansas and Pacific Railroad, the drainage of 45,000 acres during a rain of 30 minutes filled a reservoir of 158 acres, 18 feet deep over the central 60 acres. Seventy acres of the land irrigated from the reservoir produced more than 200 tons of millet and sugar corn.

Torrential rains occur invariably in July and August, doing the least good to the crops. These storms amount to more than half the rainfall, and pass over the land with but little if any percolation wherever the natural grasses remain. Whenever any considerable bare spot occurs the ground after rain will be moist for 15 or 20 feet below the surface. Wherever there is grass the rain will not sink more than 6 inches.

These instances afford an idea of the facility of reclaiming small tracts, which in the aggregate would amount to 30 per cent of the land that can be reclaimed in Eastern Colorado. In a line west from Agate, towards Denver, there are 70,000 acres that might cheaply be reclaimed from the drainage of the divide between the Arkansas and Platte rivers.

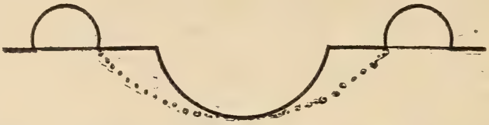
Mr. H. P. Holbrook, civil engineer of Pueblo, Colo., is of opinion that not one-tenth part of the high-water flow of the Arkansas River is utilized. The numerous canals and ditches will remedy this to some extent, having the effect of storage reservoirs. They also fill the ground with water, which slowly percolating back to the river preserves a more equal flow throughout the year. The irrigated land thus acts as a reservoir in which is preserved for future use all the water not lost in the first evaporation and the nourishment of the crops.

IN THE SAN LUIS VALLEY.

A mountain park, the lowest level of which is 7,000 feet above tidewater, 200 miles long by an average of 40 wide, embracing in its area the arable portion of Rio Grande, Saguache, Costilla, and Conejos counties, is known as San Luis Park or Valley. It is walled in by the Sangre de Cristo Mountains and the main range of the Rockies. On the east the Sierra Blanca and the Spanish Peaks rise at the highest point to 14,464 feet above the sea, and on the west towers the Continental Divide. An enormous drainage is precipitated from the snowy ranges through some twenty-three water courses, while many small streams start into the valley whose flow is quickly absorbed by the arid soil. They are either lost to sight, form quagmires or cienagas. The Rio Grande River enters from the west, running east to about the center and then south to the outlet of the park. It forms the principal source of supply for the large canals. The bed of the Rio Grande is now almost along the highest ground or divide of the valley, and its waters may be taken out with little difficulty to the lands on both sides of the river. The geologic evidence is however apparent that at one time this river turned north in the form of a huge horseshoe, and ran through the trough of the valley. Agriculture by irrigation in San Luis Valley is carried on under the Mexican, Mormon, and American plans. The first is unimportant, and the second only of small area, principally around La Jara.

There are more than five hundred ditches, large and small, in the valley, the principal of which are the Empire, San Louis, Rio Grande, and Monte Vista. The Empire is the oldest of the large canals, and when all possibilities are taken into consideration, may irrigate 300,000 acres. On August 11, 1891, one hundred and sixty-four water rights had been sold to individual farmers, each of which will irrigate 80 acres. The canal is 80 feet wide on the bottom, with a slope of sides of 3 feet horizontal to 1 foot vertical, and 6 feet deep, with a fall varying from 20 inches to 2½ feet per mile, according to the character of the soil. This canal takes water to the land on the south side of the Rio Grande. It is 40 miles long, has eight main laterals of an average bottom width of 10 feet and an aggregate length of 100 miles. The San Luis is the next large canal, and it is 40 feet on the bottom, with a slope of sides of 1½ feet horizontal to 1 foot vertical, with a 5-foot berme or embankment on each side, 6 feet deep, with a fall of 2½ feet to the mile.

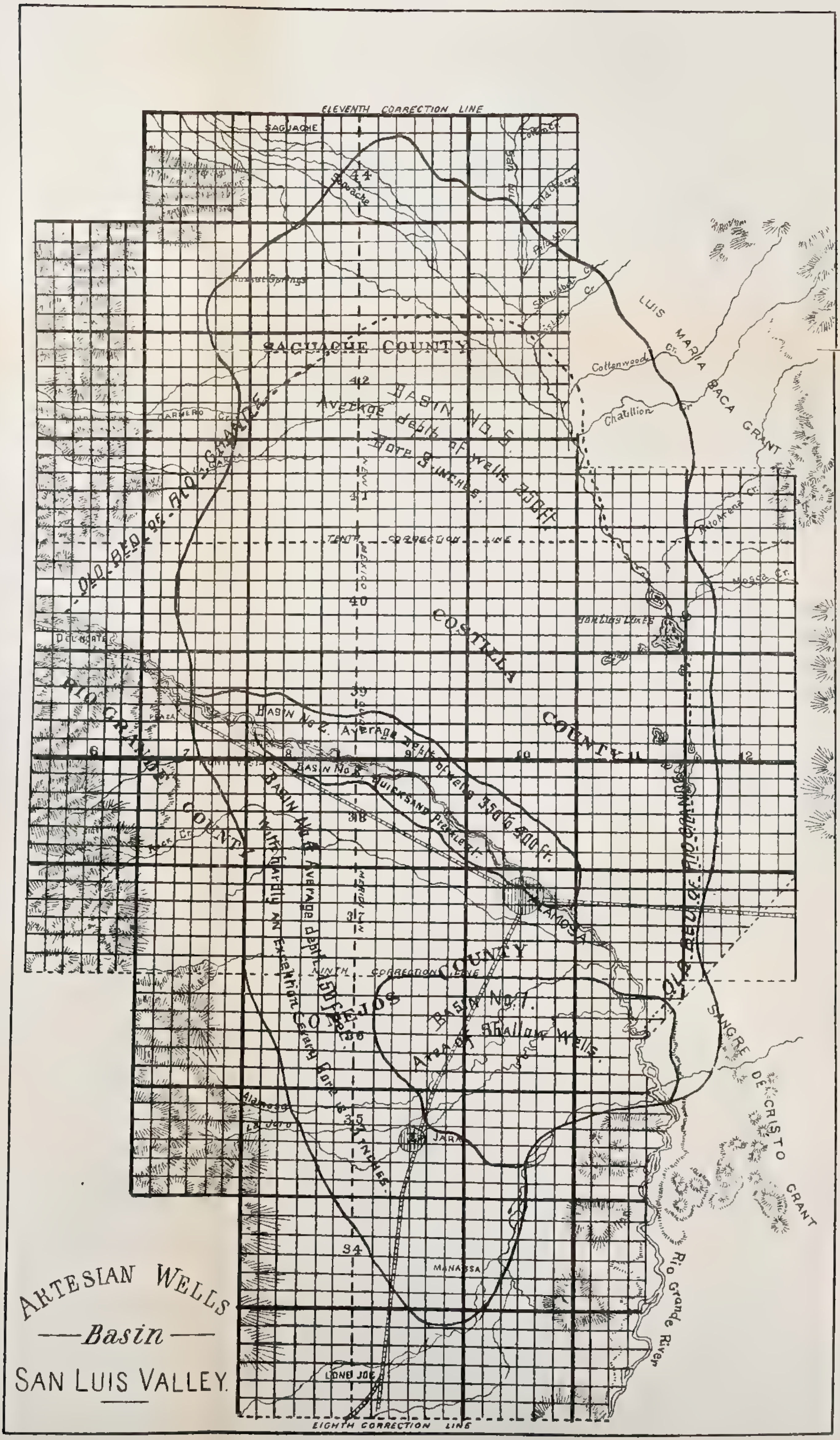
When first constructed the solid lines in the above cut represent the appearance of the ditch and berme; the dotted lines the appearance and size of the ditch after a few years' use and the sharp contours left by the excavation have been worn away. The main canal is only 5 miles long, and it then divides into two laterals each 15 miles long, 20 feet bottom width, 4 feet deep, of similar construction to the main ditch, but with a fall of 5 feet to the mile. The duty of this canal is estimated at 100,000 acres.



These two large canals are part of the great system of irrigation known in Colorado as the Henry canals, and were organized and built under the supervision of Mr. T. C. Henry, C. E. The companies control in the San Luis Valley, by purchase and lease from the State of Colorado, 155,000 acres of land on both sides of the river. This is held from the State on condition of improvement by irrigation.

The Del Norte or Rio Grande Canal was the next taken out of the river. It has an 80-foot bottom, 2 to 1 foot slope of sides, 6 feet deep, and 5 feet fall per mile. There are 80 miles of main ditch, and 100 miles of main laterals, which will irrigate 300,000 acres. Mr. Walter H. Graves was the engineer. The Monte Vista Canal is 40 feet on bottom, 5 feet deep, 2 to 1 slope, and 2½ feet fall to the mile. It is 40 miles long and has 60 miles of main lateral, with about 200 miles of distributing laterals, and will irrigate 150,000 acres. On the first of June, 1891, twenty-five 80-acre water rights under the Monte Vista, and one hundred and eleven 80 acre rights under the Rio Grande Canal had been sold to individuals. These canals are owned by the Travelers' Insurance Company. Besides the water rights sold to irrigators the company cultivates under these ditches, 23,560 acres of land in eight farms, of an average size of 2,945 acres, and varying from 7,640 to 160 acres. Under the Henry canals about twice this amount of land is cultivated in four farms, the largest of which is the Empire farm of 19,000 acres. The bulk of cultivation on these immense tracts is done by machinery, and the yields are not so large as on the smaller farms individually owned. The cultivators live in bunk houses, or shanties, and the scene on one of these corporation farms is very different from that presented in the greater part of the irrigated region, where each oasis of reclaimed land is ornamented by the tasteful homes and beautiful foliage of the door yards of the farmers. The corporations offer the settler the improved land with a permanent water right, at prices varying from $15 to $35 per acre. This farming is the direct growth of the law of Colorado, which requires the owners of lands purchased from the State not only to build the ditches to cover them with water, but to actually cultivate either themselves or by their agents all the land purchased or leased before an absolute title is effected.

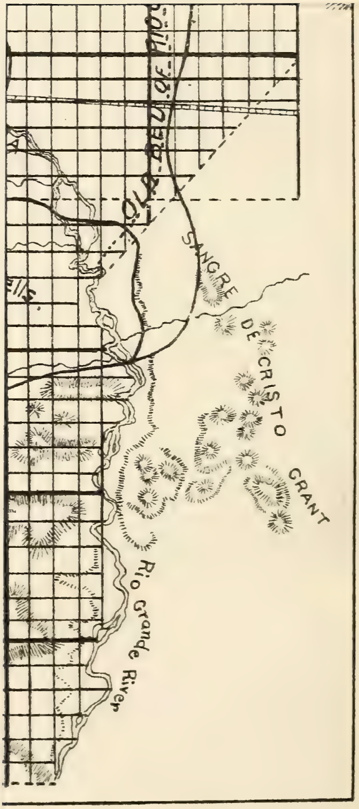
In many parts of the San Luis Valley, since irrigation has been widely practiced, large areas of land from which crops are raised receive their water by means of what is locally termed "sub-irrigation." The subsoil under these tracts is a stiff adobe, easily and quickly saturated with water, but very slow to transmit it. This brings the water table very near the surface in some places, and no water is applied to the surface at all. In other areas small farm laterals are run along the highest part of the land to be irrigated, and the water will seep for



ARTESIAN WELLS

—Basin—

SAN LUIS VALLEY.


OLD BED OF RIO
SANGRE DE CRISTO GRANT
Rio Grande River

1,000 feet, giving ample sustenance to the crop. Sub-irrigation is cheap and lands susceptible to its influence are among the most valuable of the San Luis Valley.

THE SAN LUIS ARTESIAN WELLS.

There are now about 3,700 flowing artesian wells in the San Luis Valley, but of these only three are deep wells of large bore. Two are 6-inch wells at Alamosa and the other is an 8-inch bore at Moffat. A correspondent describes the last-named well as spouting a "stream like a stovepipe, 10 feet high, without a break." This well was struck since the investigation made by this office, and the above is not known to be a fact. The two 6-inch wells at Alamosa flow about 8 inches above the 6-inch bore, but if confined to 2 inches will throw a stream 45 feet high. The strata encountered in all wells is generally—

Soil	3 to 6 feet
Sand and gravel, alternate layers	20 to 50 feet
Blue clay and sand, alternate layers	to water

Besides these wells mentioned there are in the valley about 25 wells of from 3 to 4 inch bore and not more than 800 feet deep, generally about 700 feet. Only about 10 per cent of the total number of wells penetrate to a depth of 700 feet, and barely 15 per cent go down 400 feet. No rock strata has been encountered, but the clay is of a very hard, close texture, the grain of which is so fine that it can be bitten through with the teeth without detecting the slightest grit. The sand is, however, very sharp. The best flow, except in the instances of the three deep wells named is from a stratum at about 150 to 350 feet deep.

The accompanying map of the artesian basin and the old course of the Rio Grande River was made by the departmental agent during his examination of this valley last May. The exterior boundaries of the artesian basin vary but the slightest degree, at one or two points, from the line laid down by Prof. Louis G. Carpenter in a map accompanying one of his latest reports. The professor's map, however, presents none of the lines of the subsidiary basins and is not as full in other respects. The artesian area of the San Luis Valley is divided into five distinct minor basins as set forth on the map, which is so full as to need no further illumination. The north line of basin No. 2 is the valley divide; lateral No. 2 of the San Luis Canal is along this ridge. Just across the river in basin No. 3; the stratum seems to make a huge dip, and it is with the greatest difficulty that a well can be maintained on account of the quicksand. Artesian wells are little used for irrigation at present, because only a part of the land capable of irrigation by the water in sight from the various sources of surface supply has been cultivated. The Alamosa "town well," as reported by City Surveyor and Engineer Jones, is the principal source of supply for the 30 miles of irrigating ditches within the corporate limits of Alamosa. One of the factors to be considered in the study of the San Luis artesian basins is the vast underflow of the Rio Grande. During the low stages of the water the six large canals taking water from that river between Del Norte and Alamosa throw solid sack dams across the river at their headgates. At each dam every drop of surface water in the river is stopped and diverted into the ditch, leaving the river bed dry just beyond the dam. Within a quarter of a mile, however, the river begins to fill again from the bottom and sides, and although in the short stretch of river mentioned it is dammed six times, at Alamosa there is more water in the river at the lowest stage than was the case before the canals were taken out and the water diverted.

The soil and the climate of the San Luis are eminently fitted for the cultivation of all the root crops, and the hardy fruits and berries prosper. In the upper part of Saguache County, at the northern part of the valley, some fine apples were gathered by Mrs. A. L. Lyons from two year-old trees; and from a plot of ground 50 by 70 feet, planted to red currants, Mr. Bonner sold 488 quarts of fruit worth $71.40, or at the rate of $900 per acre. Crab trees will bear the first year after planting, and yield good crops the second; natural grasses cover nearly the entire valley, and comprise gramma, bunch, buffalo, wild redtop, blue joint, wire grass, wild millet, and dozens of other varieties. The land, with irrigation, produces oats, 60 to 80 bushels per acre; wheat, 35 to 50 bushels per acre; barley, 40 to 60 bushels per acre; peas, 30 to 50 bushels per acre; potatoes, 100 to 400 bushels per acre. All hardy vegetables do well; hay from 1 to 3 tons per acre; hops are a natural product and yield abundantly. Prices of grain at nearest markets range from $1 to $2 per hundredweight; potatoes, from 75 cents to $1.25; hay, from $10 to $15 per ton, baled. Michael White, assessor of Saguache County, gives the following as his experience of farming by irrigation in the San Luis Valley:

Wheat	bushels per acre	30
Oats	do	35
Barley	do	40
Pease	do	40
Potatoes	do	175
Grasses:		
Alfalfa (two cuttings)	tons per acre	4½
Native grass	do	1½

The yields for some of the crops, it will be noted, are very high for averages, but under reasonably good farming experienced men may greatly increase these figures.

Under the four canals mentioned, 69,000 acres of land are cultivated by the ditch companies, and 41,760 acres by the owners of water rights, making a total of 110,760 acres.

Small canals from the Rio Grande River, Sagauche, Trenchara, Alamosa, and San Luis creeks, and other small streams, afford water for about 165,000 acres more, all under close cultivation and in the hands of small farmers. There are about 610,000 acres under ditch in the San Luis Valley, and 1,100 miles of main canal.

It may be said, however, that the possible area of cultivation is equal to the arable extent of the basin. The level valley floor seldom needs further preparation for farming than grubbing out the natural growth, which may be generally done by deep plowing. The land is worn as even as the bed of a long-used reservoir from which the water has been allowed to drain. No serious trouble is experienced from alkali, and when adequate population seek homes on its fertile acres, it is well within the bounds to say that the soil alone will support a large population. The great trouble in farming heretofore in this region is that the stockmen, desirous of reserving winter forage for their herds, have systematically opposed agricultural settlement. The problem of control of the valley has, however, been solved, and the rapid construction of railroads assures the steady growth and prosperous life of the communities within this region.

Irrigation by Seepage. San Luis Valley, Colorado.

ANSWERS FROM CORRESPONDENTS.

The following summaries are made from replies received to circulars sent by this office:

ARAPAHOE COUNTY.

J. A. Clough, Denver (October, 1891):

Total area in State under canals, about 5,000,000 acres.
Under cultivation under the smaller and older canals, 75 per cent; under the newer and larger canals, 25 per cent.
Average cost per acre of irrigation works, canals, etc: For the larger canals, from $6.25 to $8; for the smaller canals, from $8 to $12.
Cost per acre for annual maintenance and repairs for smaller canals, about 40 cents; for larger canals, from 15 to 25 cents.
Average cost per acre for preparing land for cultivation by irrigation: Breaking, $2; removing sagebrush, 50 cents; farm laterals, 25 cents.
Staple products under irrigation: Wheat, oats, barley, millet, potatoes (and in the smaller valleys), corn—in the order of their acreage; also clover, timothy, and alfalfa hay, and peaches, apples, pears, plums, apricots, and all small fruits yield abundantly.
Yield per acre: Wheat, 25 bushels; oats, 45 bushels; barley, 35 bushels; potatoes, 150 bushels; pears, 25 bushels; corn, 30 bushels; clover and timothy, 2½ tons; alfalfa, 5 tons.

Denver (post-office), W. E. Alexander (secretary, etc., Denver Land and Water Storage Company), October, 1891:

Water supply, Cherry Creek. (Running stream with spring and fall floods.)
Area under ditch, 40,000 to 50,000 acres.
Area under cultivation, 3,000 acres, now being plowed and prepared for cultivation under irrigation.
Irrigation works, 32 miles main canal; 18 feet wide on bottom; 3 feet through cut; 40 miles main laterals; 4 feet wide at bottom. Masonry dam, 68 feet high, 635 feet long, 83 feet wide at center. One subreservoir, earthen embankment; area, 69½ acres; 30 feet deep. (Three others projected.)
Cost: Main reservoir, subreservoirs, and canals have cost $439,000 to date, and $75,000 to $100,000 more will be expended.
Average cost per acre for preparing land for cultivation under irrigation, from $2 to $5.
Average cost per acre of irrigation works, ditches, etc., from $5 to $15.
Average cost per acre for annual maintenance and repair, 50 cents to $1.50.
Annual rental cost for water, $2 per acre.
Products: Potatoes, alfalfa, and all garden truck. Soil *especially* adapted to growth of apples, pears, plums, prunes, grapes, and berries, etc.
Estimated value of products per acre, from $250 to $600.

Denver (post-office), C. J. Combs (October, 1891):

Has 15½ acres under ditch and cultivation; takes his water supply from "Rocky Mountain ditch" by means of one-quarter mile of small private ditch or lateral.

[Rocky Mountain ditch takes its supply from Clear Creek, near Golden, Jefferson County. Its length is about 15 miles. Width, top, 12 feet; bottom, 10 feet. Area under this ditch, 5,000 acres; capacity, about 5,000 inches. Rate of use of water averages 1 inch per acre, costing from $1.25 to $2 per inch. Cost of maintenance and repairs per acre per annum, about $2.50.]

Products, small fruits and orchards. (Farther from city, grain and alfalfa.)
Value of small fruits per acre, from $200 to $1,000, gross.

Denver (post-office), Thomas B. Croke (September, 1891):

Has prepared and placed under cultivation by irrigation 1,600 acres, (by building the lateral ditches and reservoirs), at a cost of $18,000, the reservoirs costing $16,000 of this sum.
Cost of water rights and laterals (when main ditch was first built) was an average of $10 per acre.
Cost of annual maintenance and repairs per acre, not to exceed 50 cents.
Area under ditch in neighborhood ,50,000 acres.
Area under cultivation in neighborhood, 12,000 acres.
Principal products: Wheat, oats, barley, corn (of short season varieties), potatoes, alfalfa, clover, timothy, and all garden products; also all kinds of fruits (except tropical).

His own crops have averaged $10 per acre net for four past years; good hay land will average about the same.

BOULDER COUNTY.

Hygiene (post-office), James Ackerman (October, 1891):

Cost of preparing 80-acre tracts of land for cultivation by irrigation (breaking, $300; lateral ditches, $25; fencing, $150), $475.

Cost per acre of irrigation works, ditches, etc., about $10.

Cost per acre for annual maintenance and repairs, about 50 cents.

Area under ditch, 90 per cent of neighborhood lands.

Staple products: All kinds of small grain and vegetables, all kinds of fruit (except peach and apricots).

Average value of product per acre: Grain, $15; fruit, $100.

Langford (post-office), C. E. Barber (Setember, 1891):

Cost per acre of preparing land for cultivation by irrigation, $5.

Cost per acre of irrigation works, ditches, etc.: For a 10-mile ditch carrying 5,000 inches of water, covering 4,000 acres, $40,000 or $10 per acre (average of four ditches in neighborhood).

Cost per acre of annual maintenance and repairs, 10 cents (on a 10-mile ditch). Chief products (by irrigation) and yield per acre: Wheat, 20 bushels; oats, 40 bushels); corn, 30 bushels; alfalfa, 8 tons.

Grazing land is not irrigated.

CHAFFEE COUNTY.

Riverside (post-office), George Leonhardy (September, 1891):

Has 550 "acres under ditch;" 160 acres under cultivation.

Water supply, Arkansas River, has two ditches (supplying 400 miner's inches). Combined length, 5 miles; width at bottom, 4 and 6 feet; top, 6 and 8 feet; head gates, 2.

Cost per mile of ditches, etc., $2,500.

Cost per acre of ditches, etc., $15.

Cost of water to user per acre, $10.

Annual rental per acre, $2.

Cost of annual maintenance and repairs per acre, 50 cents.

Cost of preparing land for irrigation (fencing and clearing), $2 to $15.

Area under ditch in neighborhood, 1,500 acres.

Area under cultivation in neighborhood, 500 acres.

Chief products (under irrigation): Wheat, oats, barley, rye, potatoes, peas, turnips.

Value of annual crops, $20 per acre.

CONEJOS, COSTILLA, RIO GRANDE, AND SAGUACHE COUNTIES.

R. C. Nisbet (Dawkins, Pueblo County, December 10, 1891) writes of the San Luis Valley as follows:

Main water supply, Rio Grande River, its tributaries and artesian wells.

Area under ditch, 2,000,000 acres.

Area under cultivation, 100,000 acres.

"The Rio Grande system covers the above-named four counties, an area of about 60 miles square. There are twenty-six streams flowing into San Luis Valley and but one flowing out, hence the large artesian supply."

Irrigation works, about 4,000 miles of ditches; seven large canals; largest 60 feet wide on bottom; other six are 40 feet wide on bottom; about five hundred ditches, large and small, with separate head gates. There are "hundreds" of artesian wells; no reservoirs.

Cost of ditches and wells: Ditches, from 10 cents to 12 cents per yard, land level. Artesian wells cost from 25 cents to 60 cents per foot, including pipe (not over 2 inches).

Cost per acre of ditches, "taking all the land covered by the ditches, $1.50 to $2 per acre would construct them."

Average cost per acre for preparing land for cultivation through irrigation: About one-half the land is prairie, requiring merely plowing; other half sagebrush, greasewood, or chico, costing for clearing, etc., from $1 to $1.50.

Average cost per acre for maintenance and repairs, from 20 to 30 cents.

Cost of water supply to user, $500 for 80-acre tract (perpetual water right).
Annual rental cost, $1 per acre.
Staple products and average annual yield per acre: Wheat, 25 to 30 bushels; oats and barley, 40 to 50 bushels; potatoes, 175 to 200 bushels.

CONEJOS COUNTY.

Alameda (post-office), L. W. Smith (October 3, 1891):

Whole township (except three ranches having artesian supply) served by Empire Canal, with supply from Rio Grande del Norte River; 30 miles canals or ditches; width at top 60 feet, botttom 40 feet; two head gates.
Cost of irrigation per acre, with supply from river by canals or ditches, $8.00.
Cost of irrigation per acre, with supply from artesian sources (with reservoirs, etc.) $7.50.
Cost of annual maintenance and repairs, per acre 20 cents.
Chief products (by irrigation) and yield per acre: Wheat (30 bushels), oats (50 bushels), barley (40 bushels), potatoes (250 bushels), alfalfa, and vegetables.

[Mr. Smith has 160 acres under cultivation by means of artesian irrigation; states that artesian supply is easily obtained, etc.; cheapest and most permanent; that canal and ditch supply is good for only four months in the year. Two other large ranches have artesian wells, but no data of same is given.]

COSTILLA COUNTY.

San Luis (post-office), E. C. Van Diest (October, 1891):

Water supply, Rio Grande River, Sangre de Cristo, Ute, Trinchora, Culebra, and Castilla Creeks.
Area under ditch, 100,000 acres; area under cultivation, 65,000 acres.
Irrigation works (mileage and size of canals and ditches not given): One reservoir (not completed), storage capacity over 127 acres (27 to 30 million cubic feet); dam 1,300 feet long; height, 18 feet.
Cost per acre: Large canals, $1.00 to $1.60; smaller farm ditches, 75 cents to $1.00.
Cost per acre for preparing land for cultivation by irrigation: Grubbing (sage brush) $1.30; plowing, $2.15; subsidiary ditches, $1.00—$4.45; fencing (wire), $1.60.
Cost per acre for maintenance and repairs, per annum: Large canals and ditches, 70 cents to $1.00; small canal and ditches, 25 cents to $1.00.
Products and yield per acre: Oats (25 bushels), wheat (22 bushels), barley (24 bushels), hay (1 ton), peas, Mexican beans, potatoes, alfalfa (limited), upland hay.

EL PASO COUNTY.

Colorado City (post-office), A. Z. Sheldon (September, 1891):

Water supply, Fontaine qui, Bouille River, and tributaries, South Platte, Four-Mile Creek, Big Sandy Creek, Horse Creek, Rule Creek, West Creek, Trout Creek, etc.
Works, 220 miles main ditches; varying from 12 to 18 feet wide at top and 2 to 4 feet on bottom; seventy-five reservoirs, with areas of from 1 acre to 80 acres; head gates, about fifty (about fifty main ditches, each supposed to have a head gate).
Cost of reservoirs, from $300 to $25,000.
Cost of ditches per mile, from $300 to $1,000 (approximately).
Cost of ditches, etc., per acre, about $5 (approximately).
Cost of preparing land for cultivation by irrigation (plowing), $2.50 per acre.
Cost for annual maintenance and repairs per acre, about 30 cents.
Area under ditch, 20,000 acres.
Area under cultivation, 12,000 acres.
Staple products and annual yield per acre: Wheat, 25 bushels; oats, 40 bushels; corn, 50 bushels; barley, rye, potatoes, 200 bushels; hay, 1½ tons; cabbage and other vegetables, fruits of temperate zone, and grasses.

FREMONT COUNTY.

Cañon City (post-office), Ute Park improvement Company (September, 1891), land probably near Beaver Creek (post-office):

Area under ditch, 3,500 acres; water supply, Beaver Creek.
Irrigation works, 7 miles main canal; width, 8 feet top, 6 feet bottom; 2 feet deep; grade of 2 inches to 100 feet; capacity, 60 cubic feet per second; 10 miles laterals; reservoir covers 117 acres; dam, 40 feet at greatest height; one head gate (under construction).

Cost of main canal per mile, about $1,000.
Cost of reservoirs, about $10,000.
Cost of water supply to user, per acre, $10; permanent right.
Value of land without water supply, not worth occupying.
Value of land with water supply, $100 per acre.
Products under irrigation: Apples, pears, peaches, apricots, alfalfa, potatoes and all fruits and vegetables of the temperate zone. (Land, etc., fitted for the growth of wheat, oats, barley, rye, etc., but fruits, etc., considered most valuable crops.) Alfalfa is cut three to four times a year, and yields as high as 5 to 7 tons per acre per annum; worth $6 per ton.

An artesian well struck in vicinity, flowing 3 cubic feet per second.

Cañon City (post-office), Thomas S. Wells (October, 1891):

System includes 5 miles of ordinary canals on each side of Arkansas River (10 miles); each canal 12 feet wide; two head gates; area under ditch about 4,000 acres; area under cultivation, 2,500 acres.
Cost per mile of works about $1,200.
Cost per acre of works, $3 for main, $1 for laterals.
Cost per acre for maintenance and repairs, 80 cents to $1.
Cost per acre for preparing land for cultivation by irrigation, same as breaking ordinary prairie, merely plowing.
Cost per acre of water to user: Ditch owned by land owners.
Staple products under system: Fruit, garden stuff, and alfalfa.
Value of products: Fruit and garden yields $150 per acre; alfalfa produces about 5 tons per acre; value, $45 per acre.

GARFIELD AND PITKIN COUNTIES.

J. C. Kennedy, C. E. (secretary and general manager Thompson Irrigation Land and Water Supply Company, of Steamboat Springs, Routt County):

Water supply, north and middle forks Thompson Creek; supply, perennial; capacity, 80 cubic feet per second.
Works, two ditches, 17 and 18 miles in length; the 17-mile ditch uses for 7 miles the natural channel of a small stream, Edgerton Creek; width 12 feet at top, 8 feet at bottom, 2 feet deep, increasing in size as new streams are tapped; 10 or more reservoirs; 17 head gates on both ditches (size of dams, etc., not given).
Area under ditch, 11,000 acres; under cultivation, 200 acres.
Cost per mile of ditches about $600; cost of water supply per acre, $4 (estimated).
Cost of preparation of land for cultivation by irrigation, $6 per acre.
Average cost per acre of irrigation works, $4.
Products: Wheat, oats, rye, barley, potatoes, and other vegetables, alfalfa, etc.

KIOWA COUNTY.

Arlington (post-office), J. W. Parker, secretary, Sand Arroyo and Triple Lake Canal Company (September, 1891).

Area under ditch by this system, 1,300 acres.
Water supply, Sand Arroyo Creek; irrigation works (in progress), 4 miles main canal; 7 miles laterals; three reservoirs (areas 40 acres, 69 acres, and 71 acres); main canal, 10 feet wide, 2 to 5 feet deep; outlets of reservoirs, 12 feet wide (top), 4 feet (bottom), 7 feet deep.
Cost of canals (or ditches) per mile, $75 to $150.
Cost of preparing land for cultivation by irrigation, $3.50 per acre.
Cost of water per year, $1 per acre.
Cost of water, perpetual water right, $7 per acre.
Cost of annual maintenance and repairs, 25 cents per acre.
Products and annual yield of same: Wheat, 15 bushels; oats, 35 bushels; corn, 25 bushels; rye, 25 bushels; sorghum, 5 tons; potatoes, sweet, 50 bushels; Irish, 75 bushels; vines of all kinds grow well.

It is proposed to cultivate 200 acres next season, irrigated by this system.

LAS ANIMAS COUNTY.

Downing (post-office), S. W. De Busk; Trinidad (post-office), F. D. Wright (data for county generally):

Principal water supply: Las Animas or Purgatoire River.
Area under ditch, 51,562 acres; under cultivation, 30,020 acres. At least 50,000 acres more could be served by aid of storage works.

Irrigation works: 95 main ditches, about 300 miles total length; 10 larger ditches are from 8 to 15 miles long, 14 feet wide at top, 10 feet at bottom, 2½ feet deep; other ditches from 2 to 4 miles long, 5 to 6 feet wide at bottom, 2 feet deep; 2 reservoirs, area of one, 80 acres, area of other unknown; head gates, 95 (one to each main ditch).

Cost of ditches per mile, from $10 to $100.

Average cost per acre for irrigation works: Ditches, etc., $1 to $10.

Average cost per acre for preparing land for cultivation under irrigation, from $2.50 to $10 (mere plowing of prairie land cost $2.50 per acre; clearing land having growth of wild plum, locust, or cottonwood has cost $10 per acre).

Average cost per acre for annual maintenance and repairs, about $1.

Products and yield per acre: Alfalfa, 4 or 5 tons; blue stem, 1 ton; oats, 40 to 80 bushels; oats are generally cut and cured as hay; corn, 25 to 40 bushels; wheat, 30 bushels; barley, rye, sorghum, vegetables do well; beans average 40 bushels; apples, grapes, and garden truck.

LA PLATA COUNTY.

Durango (post-office), J. B. Harper (November, 1891):

Water supply, Florida River; area under ditch, 6,500 acres; under cultivation, 1,800 acres.

Irrigation works, open ditch on contour line; length of main ditch, 10 miles; width, top, 10½ feet; bottom, 6 feet; 3 feet deep; one headgate; no reservoirs; 250 feet flume; 8 feet wide; 4 feet deep.

Cost per mile of works, $1,900 (for main ditch).

Cost of water supply to user per acre, $10.

Cost of preparing land for cultivation through irrigation, per acre: Sagebrush land, $7; oak land, $50; pine and cedar, $20.

Average cost per acre of irrigation works, ditches, etc., about $10, as first cost. (This depends upon the amount of land furnished from one ditch.)

Cost per acre of annual maintenance and repairs, 75 cents.

Products: Wheat, oats, and alfalfa.

Estimated annual product per acre: Wheat, 20 bushels; oats, 45 bushels; alfalfa, 3½ tons (but yield increases with age).

LARIMER COUNTY.

Berthoud (post-office), S. W. Cole (September, 1891):

"Home supply ditch;" water supply, Big Thompson Creek (which rises at the foot of Long's Peak; fed by snows of mountain and foothills; the supply is ample at the first of the season and thousands of inches are wasted; later, water is much needed).

Area under ditch, 20,000 acres; under cultivation, 18,000 acres.

Irrigation works: Ditch, 20 miles long; width, 20 feet at top, 16 feet at bottom, for 15 miles, thence smaller; one stone dam at head of ditch 60 feet long, 50 feet high; one large earth dam, one-half mile long; one earth dam, one-quarter mile long; two reservoirs, each covering 400 acres; three large bulkheads; 115 small headgates. (Many farmers have private reservoirs with areas from 10 to 30 acres, 10 to 20 feet deep.) One long wooden flume about 2,000 feet.

Cost of works: Main ditch per mile, $4,000; 2 reservoirs ($20,000 each), $40,000; total cost (20-mile ditch, $80,000; reservoirs, $40,000), $120,000.

Cost of water supply to user per acre, $4; cost for maintenance and repairs per acre, 10 cents.

Average cost per acre for preparing land for irrigation: Plowing or breaking, $3; fencing (3 wire close posts), $1; surveying and making ditches inside of fence, 15 cents.

Cost of 2 miles of main lateral ditch per acre, 90 cents.

Products under irrigation: Wheat (mostly). next oats, barley, corn, potatoes, alfalfa (many acres). (For few last years nearly every farmer has started an orchard.)

Estimated values of product per acre, $14; forage, $12.

Fort Collins (post-office), A. N. Hoag (September, 1891):

"Dry Creek Ditch," water supply, Cache la Poudre River.

[An old ditch established by farmers who claim what water they need, or 50.92 cubic feet per second; average amount for three hundred days in 1891 was 25 cubic feet per second. There are twenty-four shares in ditch, worth $1,000 per share.]

Works: 12 miles main ditch; width at bottom, 12 feet at upper and 7 feet at lower end; one dam; two headgates; one weir.

Cost per mile, main ditch, $2,000.

Average cost per acre of works, about $20; average cost per acre for preparing land for cultivation (under irrigation): Breaking, $3; laterals, $1.50; fencing, $2; total, $6.50.

Average cost per acre for maintenance and repairing per annum, $1 (including laterals).

Cost of water supply per share, $1,000; annual cost for repairs, per share, $25.

Area under ditch, 2,600 acres; under cultivation, 2,300 acres.

Staple products under irrigation: Cereals, alfalfa, native hay, vegetables of all kinds, and fruit.

Value of product per acre: From $20 to $300 (fruit); alfalfa from $20 to $40.

LARIMER AND WELD COUNTIES.

Hon. B. H. Eaton, Greeley, Weld County, Larimer and Weld Canal:

Water supply, Cache la Poudre River (mountain stream); area under ditch, 40,000 acres; under cultivation, 34,000 acres; irrigation works, 52 miles; canal, 28 feet wide on bottom, 6 feet deep, with slope of 1½ to 1 foot: two large reservoirs (being constructed) with aggregate depth of 23 feet over 650 acres; many smaller (private) reservoirs; one main headgate; 90 lateral headgates.

Cost of canal per mile, $3,000.

Cost of reservoirs (two being constructed by the 500 water-right holders), $75,000 to $100,000.

Cost of water supply to user per acre (perpetual water right), $15.

Cost per annum for maintenance and repairs, $10 for 80-acre tract, or 12½ cents per acre.

Cost for preparation of land for cultivation (plowing), $2 per acre.

Staple products: Wheat (averaging 30 bushels per acre), oats, barley, alfalfa, potatoes, cabbages, onions, etc.

MESA COUNTY.

Grand Junction (post-office), C. W. Steele (October, 1891):

Water supply, Grand and Gunnison rivers and small streams.

Area under ditch, 48,000: Grand Valley, 40,000; elsewhere in county, 8,000 acres.

Area under cultivation, 15,000 acres.

Works: Grand River system, two large canals or ditches, one headgate; Gunnison River, water wheels, other works, three pumping plants, to serve 2,400 acres; ditches from smaller streams.

Mileage and size of canals: 75 miles; largest, 50 feet wide on top, 38 feet on bottom; next largest, 24 feet on bottom.

Cost per mile, main canals, $7,500.

Cost of water supply to user per acre, $10.

Annual rental cost $2.80 per inch. (Owners of water rights or royalty pay assessments of from 12½ cents to 87½ cents per acre per annum.) Average cost per acre of annual maintenance and repairs, 20 cents.

Average cost per acre of irrigation works, ditches, etc., $10 (from Grand and Gunnison rivers; less from smaller streams).

Staple products under irrigation: Wheat, oats, corn, alfalfa, fruits, potatoes, and other vegetables in variety.

Grand Junction (post-office), J. Clayton Nichols and Messrs. Crawford & Miller (October, 1891):

Grand River Canal or ditch: Water supply, Grand River (abundant supply).

Area "under ditch," from 34,000 to 45,000 acres; under cultivation, from 15,000 to 18,000 acres.

Irrigation works: Canal, 52 miles; 38 miles main canal; width, 50 feet on top, 30 feet on bottom (40 feet at headgate); one headgate; no reservoirs or other works.

Cost per mile of canal, about $6,000.

Cost of water supply to user, per acre, from $10 to $16; annual rental cost, $1 to $1.75.

Average cost per acre for preparing land for cultivation under irrigation, $2.50 to $3.

Average cost per acre for annual maintenance and repairs, 12½ cents to 62½ cents.

Average cost of irrigation works, from $5 to $16.

Staple products under irrigation: All kinds of semitropical fruits (especially peaches, pears, apples, apricots, nectarines, grapes, and almonds); also oats, wheat, corn, potatoes, and alfalfa.

Estimated value of product per acre, $15 to $25 (for oats, etc., and alfalfa); $300 to $500 for fruits.

"This valley is celebrated for its apples, peaches, pears, grapes, apricots, almonds, nectarines," etc.

Grand Junction (post-office), D. C. Hawthorne (October, 1891):

"Crawford Ranch;" has a private ditch; water supply, Rapid Creek (a mountain stream heading in the Great Mesa Mountain).

Works: Ditch, 1¼ miles in length; width at top, 4 feet; at bottom, 2½ feet; one stone dam; one headgate (cheap).

Area under ditch, 100 acres; under cultivation, 60 acres (orchard and vineyard).

Cost of ditch (1½ miles), $1,000; cost of annual maintenance and repairs, about $60.

Products: Nothing grown but fruits (except for family use); orchard set out spring of 1890.

Grand Junction (post-office), Mrs. Kate Harlow (October, 1891):

Has private ditch; water supply, Rapid Creek (which heads in Grand Mesa Mountain and empties into Grand River on her place); creek has a fall of 5,000 feet in the 6 miles of its length.

Nature of works: Ditch about one-half mile long, 3 feet wide; one headgate; also simple stone dam; no other works.

Cost of ditch, about $1,800; area under ditch, 80 acres; under cultivation, 35 acres.

Cost of maintenance and repairs per year, about $200.

Products: "Nothing but fruit and vegetables; country is new."

Grand Junction (post-office), Messrs. Miller & Wallace (October 19, 1891):

Have private ditch; water supply, Wallace Creek (which heads in Battlement Mesa Mountain); average flow, 4 cubic feet per second.

Area under ditch, 640 acres; under cultivation, 320 acres.

Works, ¾ mile of ditch, 18 inches on bottom, 3 feet on top, 18 inches deep, grade ¼ inch per rod; one headgate 3 feet wide (no reservoir).

Cost of entire ditch, $750 (about).

Average cost per acre of ditches, etc., $5.

Cost of water supply to user per acre, $2.25.

Average cost per acre for preparing land for cultivation under irrigation, $8 (sagebrush land under this ditch). Average cost for land in Grand Valley around Grand Junction, about $2.50.

Cost per acre for annual maintenance and repairs, from 10 cents to 25 cents.

Products under irrigation: Alfalfa, wheat, oats, barley, potatoes.

Estimated value of annual product, $15 per acre; irrigated grazing land, $1.50 per acre. Altitude of Wallace Creek, 6,000 feet.

Whitewater (post-office), John Goldsby (October, 1891):

Has private ditch covering 75 acres; water supply, East Creek (which empties into Gunnison River); ditch 1 mile in length, 6 feet wide at top, 2½ feet at bottom, claims 100 inches water; one reservoir dam 200 feet long, 7 feet high.

Cost of ditch, $350; cost of reservoir (dam, etc.), $450; annual repairs, etc., per annum, $1.

Cost per acre for preparing land for cultivation under irrigation $40 (land, so-called "bottom land," covered with heavy growth of willow, etc., requiring labor and money to "grub" out).

Staple products: Fruits of various kinds, alfalfa, wheat, oats, corn, and other small grains,

Annual product per acre: wheat, 30 bushels; corn, 40 bushels; oats, 75 bushels.

MONTROSE COUNTY.

Montrose (post-office); Judge John C. Bell (October, 1891); general data (estimated) for Montrose County.

Principal source of water supply, Uncompahgre River; area under ditch, 200,000 acres.

Irrigation works, about 200 miles of large and small canals and ditches; no reservoirs; head gates numerous, costing from a small amount up to $5,000.

Cost of canals, ditches, etc., per mile, widely varying; probably from $100 to $2,000.

Preparing land for cultivation by irrigation. [Most of the county is mesa land, with no wild growth but white sage, easily plowed up; some exceptional cases, where cost would be $50 per acre to prepare.]

Cost of water to user per acre, $3.25; annual rental cost, $1.25.

Cost of annual maintenance and repairs on minor ditches, merely nominal; on large canals, considerable, but varying greatly; no estimate.

Products: Wheat, oats, barley, rye, alfalfa, clover, timothy, and all kinds of vegetables and fruits. (Is a great fruit and alfalfa county, and with present prices fruit pays better than anything; alfalfa next in value.)

Yield of wheat per acre, 25 bushels, worth 80 cents per 100 pounds; oats, 60 bushels, worth $1.25 per 100 pounds.

OTERO COUNTY.

Rocky Ford (post-office); Messrs. C. G. Ament & Co. (September, 1891):

Water supply, Arkansas River. Irrigation works. Canal 80 miles in length; width, 20 feet wide on bottom, 24 feet wide at top (at the head), 8 feet wide at lower end of canal; one head gate; no reservoirs.
Area under ditch, 35,000 acres.
Area under cultivation, 5,000 acres.
Cost per mile of canal, $1,500.
Cost per acre for annual maintenance and repairs, 10 cents to 25 cents (on actual amount of water purchased).
Cost of irrigation works per acre for 160-acre tracts (all under cultivation). Water right, $1,200; laterals and head-gate, $100. (Farmers do not generally buy enough water to cover their whole farms.)
Cost per acre for preparing land for cultivation by irrigation: Breaking wild land, $1.75 per acre; for grazing, 25 cents per acre for laterals.
Cost of water supply to user, $10 per acre (perpetual water right).
Products and yield (of same) per acre: Wheat (25 bushels), oats (35 bushels), corn (30 bushels), beans (20 bushels) alfalfa, hay), 6 tons; seed (5 bushels), sweet potatoes, melons, and all "truck" raised extensively.

Catlin (post-office); Robert McLain (October 25, 1891):

Water supply, Arkansas River; area under ditch, 15,000 acres.
Area under cultivation, 13,000 acres.
Irrigation works:
Large canal, length 35 miles; width, top, 30 to 38 feet; bottom, 20 feet.
One dam across river (308 feet long, 16 feet wide), of lumber and piles.
One head gate; no reservoirs.
Cost per mile of works, about $1,800.
Cost of water supply per acre, $10. (Perpetual water right.)
Cost of preparation of land for cultivation (per acre), by irrigation, $2.50.
Cost of preparation of land for grazing (per acre) by irrigation, $1 (grass).
Cost of maintenance and repairs per annum, per acre, about 15 cents.
Annual rental cost of water, $1.50 per acre (when sold by the year).
Staple products (and yield per acre) under irrigation: Wheat (25 to 40 bushels), oats (30 to 60 bushels), corn (25 to 40 bushels), hay (3 tons), alfalfa, beans, sweet potatoes, and other vegetables.

La Junta (post-office); C. R. McBride (October 5, 1891):

Arkansas Valley Canal, supply, Arkansas River (north side).
Length of canal, 120 miles; width, 60 feet at top; 30 feet bottom (at headgate); 2 reservoirs.
Head gates, 100; area under ditch, 165,000 acres: under cultivation, 32,000 acres.
Cost per mile: Ditches, $3,000; cost of reservoirs, etc, $5,000.
Average cost per acre of irrigation works, $5.50.
Average cost per acre for preparing land for cultivation by irrigation, $6.
Average cost per acre for maintenance and repairs per annum, 15 cents.
Cost of water supply to users per acre, $12.50.
Annual rental cost per acre, $1.50.
Products under irrigation and yield of same per acre: Alfalfa (4 tons), wheat (25 bushels), corn (30 bushels), oats (50 bushes), barley (30 bushels). Vegetables and fruits grow to perfection.

La Junta (post-office); J. H. Nelson (October, 1891), chief engineer Colorado Irrigation Canal Company:

Irrigation Works, Otero Canal; Water supply, Arkansas River (south sine; canal 105 miles long; width top, 32 feet; bottom, 20 feet; five flumes; two headgates; one waste gate; no reservoirs.
Average cost per mile of works, $3,000; average cost per acre, $5.50.
Average cost per acre for preparing land for cultivation: Plowing, $1.75; laterals, 5 cents ($2.25); fencing, $1.
Average cost per acre for maintenance and repairs, 15 cents.
Average cost of water to user per acre, $10 (water right).
Area under ditch, 74,000 acres; under cultivation, 18,000 acres.
Products (under irrigation) and yield per acre per annum: Alfalfa (4 to 5 tons), wheat (24 bushels), oats (4 to 5 bushels), corn (30 bushels), rye (20 bushels) clover (3 tons), timothy (2 tons), berries, grapes, and other fruits and vegetable.

PROWERS COUNTY.

Lamar (post-office); Santa Fe Land and Canal Company (November 21, 1891):

Source of supply, the Arkansas River. Canal being constructed to be 65 miles long; width on top, 26 feet; on bottom, 16 feet; depth, 5 feet; number of head gates, 3; cost per mile (average) $500; cost of works per acre, $7.50; cost of water supply to user per acre, $10 (water rights).
Cost of maintenance and repairs per annum per acre, 15 cents.
Cost of preparing land for irrigation, $2.40; plowing, $2; harrowing, 40 cents, per acre.
Area under ditch, 30,000.
Staple products (under irrigation): Alfalfa, wheat, oats, millet, vegetables and melons.
Estimated annual product per acre: Alfalfa, 8 tons; wheat, 40 bushels; oats, 25 bushels.

Lamar (post-office); D. E. Cooper, secretary Bed Rock Mutual Ditch Company (October 30, 1891):

Water supply, Arkansas River.
Area under ditch, 4,500 acres.
Area under cultivation, 1,060 acres.
Length of canal, 11 miles; width at top, 12 feet; at bottom, 8 feet; 3 feet fall per mile.
Two head gates; no reservoirs.
Cost per mile of ditches, $450.
Cost of water supply to user per acre, $4.60 (perpetual right to user).
Cost of preparing land for cultivation under irrigation per acre, $3.
Cost per acre of annual maintenance and repairs, 15 cents.
Products under irrigation: Wheat, oats, barley, rye, alfalfa, potatoes, corn and fruits.
Value of annual product per acre, $18.

Circular addressed to "Secretary Kansas Loan and Trust Company" was returned with data and signed as follows:

"T. B. Sweet, president Irrigation Land Company, Topeka, Kansas."

Water supply, Arkansas River (near Lamar, Prowers County, Colo.).
Irrigation works: Dam across river (no data), and 50 miles canal or ditches, 26 feet wide on top, 20 feet on bottom (being three canals brought together 2 miles east of Lamar); three head gates and some flume work (no data).
Cost of works per mile (including all works on ditches, head gates included), $2,000.
Cost of works per acre, $4 to $5.
Cost of water supply per acre to user (perpetual water right), $10.
Cost of preparation of land for cultivation by irrigation, $3.
Cost of preparation of land for grazing, native grasses, not over 50 cents.
Cost of maintenance and repairs, per acre, annually, 15 to 25 cents.
Principal products and annual product per acre: Wheat (30 bushels), oats (40 bushels), rye (30 bushels), barley (40 bushels), corn (50 bushels), alfalfa (4 to 5 tons), sweet potatoes (100 bushels), melons, etc.
Area under cultivation, 5,000 acres.
Area under ditch, 25,000 acres.

PUEBLO COUNTY.

Pueblo (post-office); R. Rosenberg, superintendent Bessemer Ditch Company (October, 1891).

Water supply, Arkansas River.
Area under ditch, 30,000 acres; area under cultivation, 7,500 acres.
Irrigation works: Mileage of ditches, 42 miles. Main canal: Width at top, 22 feet; at bottom, 6 feet; depth, 8 feet. Ten reservoirs projected. One reservoir constructed with capacity of 38,000,000 cubic feet; height of dam, 18 feet; one masonry head-gate; one siphon, 4,500 feet in length, 5 feet diameter (under St. Charles River).
Cost per mile of main ditch, $11,000; average cost per acre of laterals, $1.25.
Cost per acre for annual maintenance and repairs, 62 cents.
Cost per acre for preparing land for cultivation by irrigation, $2.50.
Staple products under irrigation—alfalfa, vegetables, grain, and maize.
Estimated annual product per acre: Alfalfa, 7 tons; grain, 30 bushels.

County statistics compiled from answers to office circulars, are from the following residents of said county: H. R. Holbrook, L. W. Smith, T. H. Brandenberg, H. T. Van Keuren, C. H. Small & Co., T. H. S. Schooley, Geo. Bell, Bardon Sweet, John Norris, C. H. Stickney, Ward Rill, Davis & McDaniel, Chas. Kretschmer, Wm. Meredith.

Estimated area in county under ditch, 300,000 acres.
Estimated area in county under cultivation, 100,000 acres.
(In immediate vicinity of Pueblo City, probably 60,000 acres under ditch.)
Water supply, Arkansas River:
Estimated average cost per acre of irrigation works in county, main ditches, etc., $10.
(Near the mountains, foothills, etc., where arroyas are found, bridges frequent, and the river banks are high, average is probably $25 per acre; on level lands, not far above river level, probably from $5 to $10 per acre.)
Average cost of water per acre, $10 (perpetual water right).
Average cost of preparing land for cultivation (by irrigation) about $3.50. (Plowing from $1.25 to $2.50; laterals, $1.25 to $1.50.)
Average cost for annual maintenance and repairs per acre, from 25 cents to $3.
Staple products under irrigation: Wheat, oats, rye, corn, barley, alfalfa, timothy, millet, blue-stem hay, potatoes, celery, sugar beets, beans, cabbage, onions and other vegetables; apples, peaches, pears, plums, grapes, melons, and all fruits of the temperate zone.
Average annual product per acre: Wheat, 20 to 30 bushels; oats, 30 to 40 bushels; corn, 40 bushels; grain generally, 20 to 40 bushels; alfalfa, 4 to 8 tons.
Average value of product per acre: Grain crops, from $20 to $30; fruit, $150; melons, $50 to $100; apples, from $100 to $200; garden truck, $250; alfalfa, $20 to $60.
Average revenue from all crops, with proper cultivation and plenty of water, from $20 to $30 per acre.

ROUTT COUNTY.

Craig (post-office), C. E. Baker (October 21, 1891).

Water supply, Snake, Bear, and Elk rivers and tributaries, ("furnishing more water than can be utilized.")
Irrigation Works, 150 miles of main canals or ditches, 6 reservoirs, covering from 3 to 25 acres.
Cost per mile of ditches, about $200.
Cost per acre for preparing land for cultivation by irrigation, average $4.
Cost per acre for annual maintenance and repairs, about 50 cents.
Cost per acre of irrigation works, ditches, etc, from $1.25 (near the mountains) to from $3 to $10 (where stream has less fall).
Products and yield per acre, under irrigation: Wheat, 30 bushels; oats, 40 bushels; potatoes, (300 bushels) and hay.

Steamboat Springs, (posto-ffice), J. C. Kennedy, C. E. (December, 1891.) Altitude, 6,700 feet.

His homestead tract has about 100 acres under two ditches taking water out of Fish Creek; 20 acres under cultivation this (the first) year; cost per acre, about $1.

"In water district No. 58 (of which he was referee this season) about 60 per cent of the water users have water rights adjudicated. Duty allowed, 1 cubic foot per second to every 60 acres. Amount of water appropriated in district 316 cubic feet per second. Total mileage of ditches, 120 miles (mostly small ones) area under ditch, about 19,000 acres, about 50 per cent of which is now irrigated."

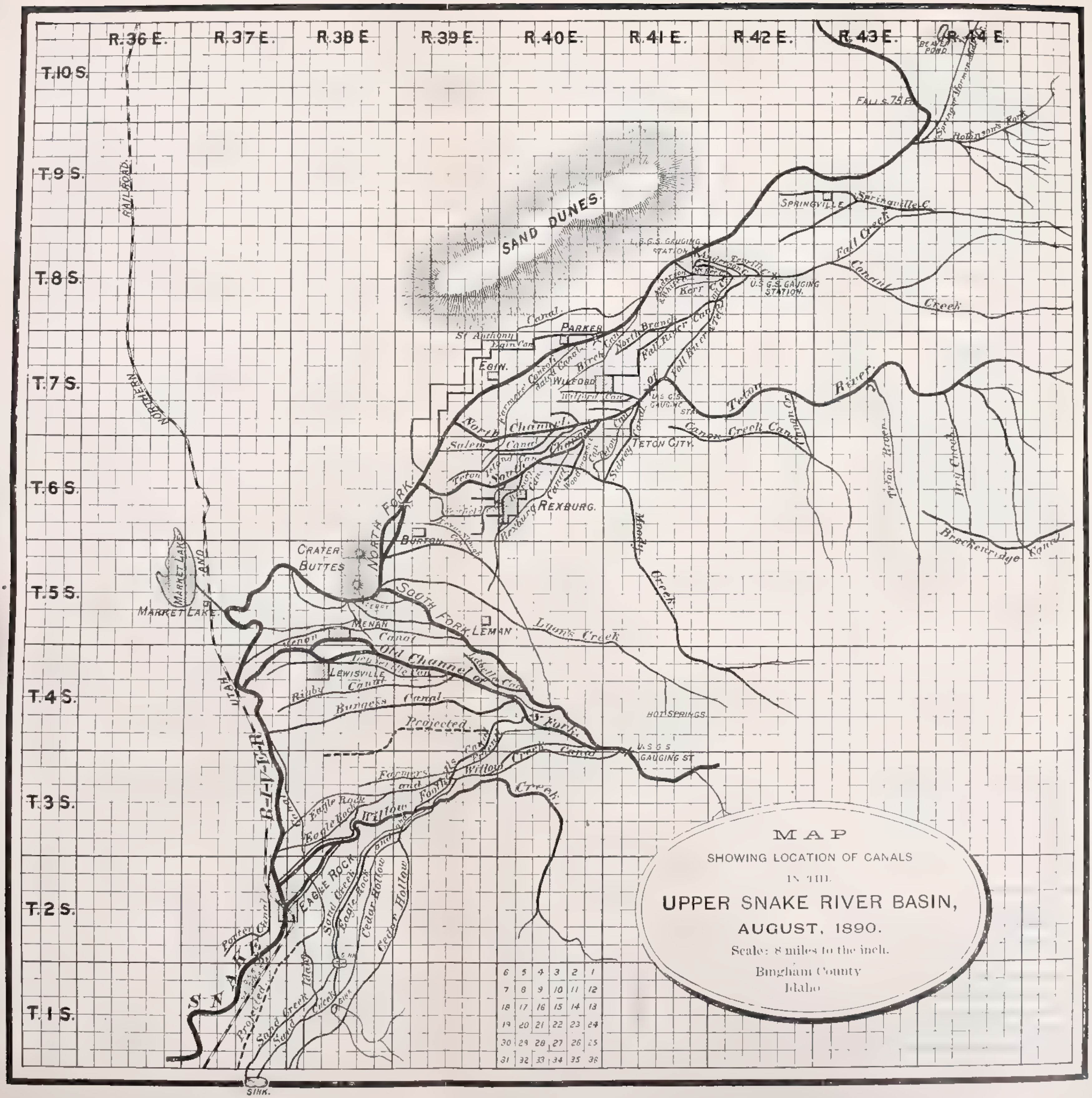
IDAHO.

Located between latitude 42° and 49° north and longitude 111° and 117.10° west of Greenwich, Idaho embraces an area of 86,294 square miles, or 55,228,160 acres. It is bounded on the north by the British Possessions and Montana, east by Montana and Wyoming, south by Utah and Wyoming, and west by Oregon and Washington. The extreme length, north and south, of its western boundary is 485 miles, while on the east along Wyoming it is but 140 miles. Its breadth is about 50 miles in the north and northeast to 300 miles in the south. The narrow portion of the Territory running between Montana on the east and southeast and Oregon and Washington on the west is known as the Panhandle. It is a region of high altitude, with large plateau and table-land areas, having numerous mountain lakes and a higher degree of humidity than any other portion of the arid region between 100° and 126° of west longitude. The remaining portions of the State consist of mountain and table lands, with an average elevation of from 2,000 to 5,000 feet above sea level. This great mountain plateau is broken by numerous depressed valleys, which form channels for some considerable streams. It is crossed also by short mountain ranges or spurs, having peaks that rise above the level, with perpetual snow. The whole area therefore is one of a great water-bearing capacity and contains many important rivers and scores of deep, placid lakes. The principal of these are: Alturas, Bear, Cliff, Cœur d'Alêne, Dry, Grays, Great Payette, Henry, Hot, Kanikau, Lincoln, Loon, North, Pend d'Oreille, Red, Fish, Swan, and Yule. The entire lake area of Idaho covers about 600,000 acres. The Pend d'Oreille is 120 miles long and from 5 to 10 miles wide. The Cœur d'Alêne is 36 miles in length and from 3 to 5 miles wide. The Kanikau is 20 miles long and 10 miles wide. These lakes and numerous others are all of them located in regions bounded by picturesque mountain ranges and having great beauty of position and scenery, which is sure in time to make them the cause of admiration by thousands of tourists.

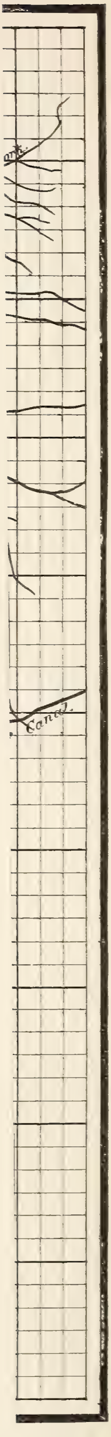
The rivers of Idaho are all of them important and some are navigable for a considerable length. Among the most important are the Salmon, Snake, Boisé, Clearwater, Kootenai, Payette, Weiser, the Clark Fork of the Great Columbia, with the Cœur d'Alêne and St. Joseph Rivers, all of them of great size. The three latter are as large as the Ohio at Wheeling and each of them is navigable for several hundred miles. The Snake River is over 1,000 miles in length within and on the borders of the State of Idaho, and is also navigable for about 200 miles. The others named are more important in size and volume than the Susquehanna and smaller streams in the East. With these there are hundreds of tributaries, nearly all of them having swift, clear, and somewhat precipitous currents, furnishing hydraulic power to an almost illimitable capacity. The storage of water is a problem of ready solution in the State of Idaho. It will require only careful engineering and thorough construction for safety in the forming of reservoirs and in the making of channels for distribution. The Snake River is one of the most remarkable streams in character for its length, formation of channel, its volcanic features, and for the second greatest cataract and rapids upon the North American Continent, Shoshone and American Falls being among the wonders of nature in volume and picturesqueness of scenery. The basin of the Snake within the boundaries of Idaho forms an almost unbroken bed of lava and basaltic rocks for 50 miles in width and throughout its entire length. The river, as cut through by this enormous volcanic area and vast cañon, varies in depth from 100 to 1,000 feet. The streams that empty from the north into the Snake form some distance below the Shoshone and American Falls. The larger portion of this remarkable basin must remain a barren waste, so far as agriculture is concerned, though the sage brush that covers much of its surface indicates considerable fertility. The deep valleys contain a large proportion of arable land, and the foothills surrounding the basins are plenteously covered with gramma and bench grass, thus affording excellent pasturage. The extreme upper and lower portions of the Snake basin may be reclaimed for agricultural purposes by means of irrigation. The river itself will unquestionably become the great source of storage water for the reclamation of southern Idaho.

The Saw Tooth Mountains and other extensions of the Bitter Root Range appear to form a climatic division. On the east side thereof, Idaho belongs to the arid area; on the west, the climate is almost humid enough to do away with irrigation altogether. It is probable that a considerable proportion of the famous Camas Prairie of the Salmon and Clark's Fork basins will be brought under cultivation; chiefly by the aid of large surface irrigation works, which are now projected. The Bitter Root Range, with its extension, the Cœur d'Alêne, forms on the northwest a continuation of the Rocky Mountain range proper, and makes a northern termination of the continental divide within the United States. The fall of rain and snow upon this mountain divide is very considerable; but both to the east and west the valleys and table lands receive but little precipitation, and agriculture will not be found successful therein without the aid of irrigation. South of the Snake River, beginning on the east, will be found the important hydrographic basin of the Bear River and Lake. Next in importance thereto are those of the Raft River, the Salmon Fall River, and the lower portion of the Bruneau, which takes its rise in northern Nevada, numerous branches and forks of the Owyhee, which also rise in northern Nevada and belong, hydrographically speaking, as does the Bruneau, to the drainage basins of that State.

The climatology of Idaho presents remarkably favorable features for a mountain region. In the eastern and southern portions of the State the annual precipitation is about ten inches. The snow on the mountain and table lands, which comprise about four-fifths of the State, will accumulate during the winter to an average of six packed acre-feet or about four acre-feet of water. On the Saw Tooth Range and other higher mountain summits twice this average is reported or estimated to fall. Hurricanes and tornadoes are altogether unknown. The influences of the Japanese current (Kuro Shiwa) is felt to a considerable extent within a large portion of western and southern Idaho. The temperature of the winds blowing from the Northwest, which is the main current observed in Idaho, is, of course, greatly affected by the influences of this warm current. As these winds pour inward, laden with moisture and warmth, they strike the bald and precipitous high altitudes of the Bitter Root and Rocky Mountain ranges, and are thereby deflected,



MAP
SHOWING LOCATION OF CANALS
IN THE
UPPER SNAKE RIVER BASIN,
AUGUST, 1890.
Scale: 8 miles to the inch.
Bingham County
Idaho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Canal.

depositing their moisture along the western slopes and base of the mountains, carrying their warmth if not their humidity to any great extent into the southern portion of the State. The forest area of Idaho was estimated by witnesses before the Senate Committee on Irrigation at 9,000,000 acres. Mr. Fernow, chief of the forestry division of the Department of Agriculture, estimates the area of timber land at 5,819,600 acres. Maj. Powell, in his testimony before the Senate committee, gives Idaho only 1,177,600 acres of both firewood and merchantable timber. His estimate is evidently as much too small as the estimate of the first witnesses is too large. The estimate of the chief of forestry is more correct. The lake or northern region of Idaho shows by far the heaviest timber or tree growth. The lake region lies chiefly within the counties of Idaho, Latah, Nez Perce, Shoshone, and Kootenai, and, with the exception of the western portion, none of this territory can be classified as arid. It may properly for irrigation purposes be termed sub-humid.

The agricultural lands of Idaho are estimated to embrace about 16,000,000 acres, of which at least 11,000,000 are of an arid character and require an artificial application of water by irrigation works to make them productive. In the new State thirteen of the eighteen counties are entirely within the arid belt. Probably one-tenthof the remaining five will require irrigation also. The soil may be divided into alkali; the rich warm loams of plain and plateau; that of the valleys andmountain slopes. The alkalized area is less in extent for Idaho, in proportion to its extent, than is found in any other mountain region. The greasewood and sagebrush grow abundantly thereon. The major portion of it so lies, that by means of irrigation it can be thoroughly reclaimed. The mountain and foothills soil, especially in the wooded section, is of a deep black loam of rich vegetable mold. The table, mesa, and plateau areas are covered with a soil highly mineralized, compounded of volcanic and granite detritus, and possessing all the elements necessary for the successful growth of the cereals. The valley lands contain a sandy soil, friable, warm, easily drained as well as irrigated, and showing a remarkable adaptability for the smaller grains, the temperate fruits, and all vegetable and garden products. It is of good depth, invariably superimposed on a gravelly strata, with a grade that facilitates easy working. The elevation of these valleys is usually less than 5,000 feet above sea level. Their fertility is greatly aided by the prevalence of the Chinook or Pacific winds. All of the cereals and vegetables which are raised north of the cotton belt grade can be raised in Idaho; even tobacco and cotton have been grown in the lower valleys. They are not likely, however, to prove a certain crop. For fruit growing, southern and western Idaho is becoming one of the most valuable portions of the arid region. The mountain basin or valley in which Boise is located, for example, presented before the Senate committee in August, 1889, a remarkable array of apples, plums, peaches, pears, and other fruits of the temperate zone. In size, quality, and quantity, the exhibit was of an almost astonishing character.

Irrigation has already obtained a large foothold in Idaho. In the southeastern portion thereof, embracing the counties of Bear Lake, Bingham, Cassia, and Oneida, the Mormon settlers have covered a considerable area with their minutely divided farms and their numerous and primary form of ditches. Westward of their settlements the ditch systems grow larger, though in total areas the surface of land served is not as extensive. The governor of Idaho Territory, in his last report for 1889 (made before admission into the Union), presented the following table, carefully prepared from reports prepared for the Senate Committee on Irrigation, under the direction of the governor and surveyor-general of the Territory:

	Areas (approximate).	Area in process of irrigation.	Area irrigable.	Land irrigated.	Land reclaimed.
	Sq. miles.	*Acres.*	*Acres.*	*Per cent.*	*Per cent.*
Ada	2,424	60,000	900,000	6.25	62
Alturas	2,100	14,500	268,000	5.13	21
Bear Lake	1,300	21,500	40,000	35.5	74
Bingham	12,364	284,750	2,503,500	10.5	35.5
Boise	3,024	83,500	262,000	24.	18.
Cassia	5,100	82,000	655,000	11.1	22.5
Custer	4,350	24,000	446,000	5.1	16.7
Fillmore	2,700	10,000	230,000	4.2	14.
Lemhi	4,300	10,000	600,000	1.64	22.2
Logan	5,200	50,000	1,250,000	2.6	39.
Oneida	2,600	38,800	148,000	20.8	11.2
Owyhee	7,812	21,300	248,500	8.	42.
Washington	2,900	40,000	500,000	7.4	29.
	56,174	740,350	8,051,000	9.2	24.

Other testimony taken by that committee gives the total of irrigated acres at 715,500, and the mileage of ditches at 13,011. It is reasonably estimated that since then about 50,000 additional acres have been brought under ditch, of which one-fourth is now being cultivated. The total cost of the irrigation works now constructed in Idaho is not less than $2,250,000.*

In the southwestern portion of Idaho, and in the valleys of the Snake and Salmon, great ditch systems are in process of construction, the cost of which will not be less than $1,500,000. They will add an additional 250,000 to 300,000 acres to the area under water. The following reservoirs are now in use for the storage and supply of water for town purposes, obtained from springs or other phreatic waters:

County.	Town.	No.	Capacity.
Bingham	Pocatello	...	Tanks supplied by springs; 500,000 gallons.
Logan	Bellevue	1	Dam and impounding reservoir.
Alturas	Hailey	1	250,000 gallons.
Do	Ketchum	1	100,000 gallons.
Oneida	Weston Creek	1	Dam and impounding reservoir.

For irrigation purposes, the county reports made to the Senate Committee on Irrigation, including sites and estimates for storage reservoirs, made estimates as follows:

County.	No.	Estimated cost.
Bear Lake	8	$38,500
Cassia	9	550,000
Oneida	2	4,000

New irrigation works in process of construction are being carried on under the direction and capital of New York and Salt Lake City parties. The Alturas Land Irrigation Company, projected in Utah, designs to construct a dam across the Snake River to flood canals for the purpose of irrigating land on both sides thereof, in Cassia and Logan Counties. It is stated that this work will serve when completed 500,000 acres of the most valuable fruit, cereal, and vegetable land. The land to be thus served is not now worth the preëmption price of $1.25 per acre.

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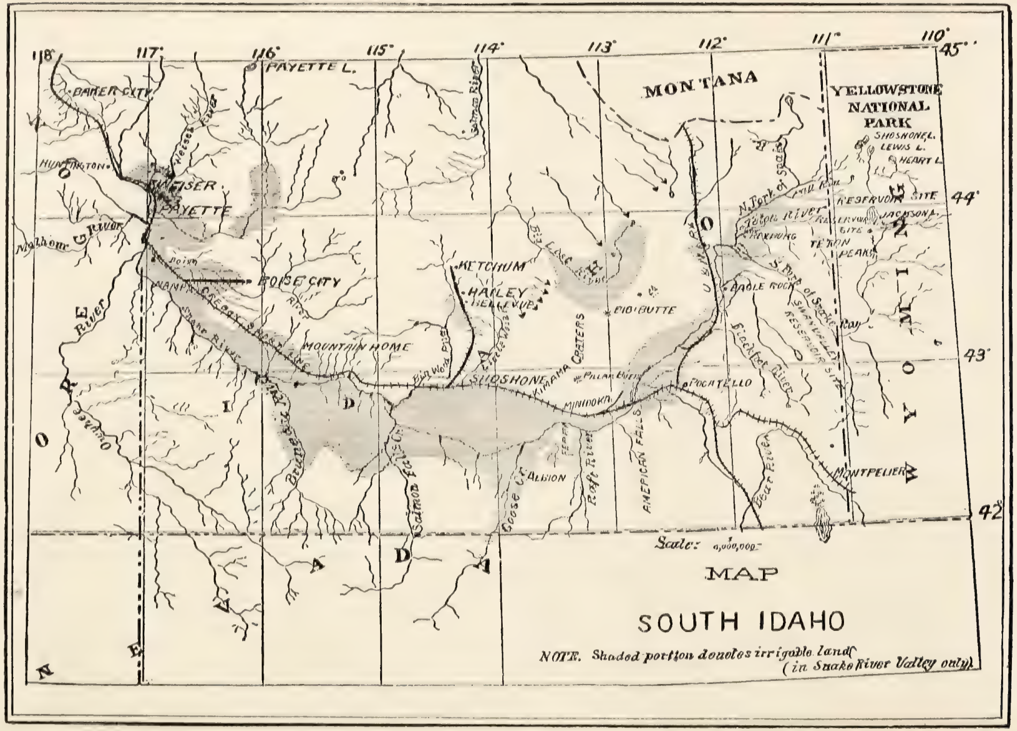
* See answers to correspondents at close of Idaho for U. S. Census figures.


118°
117°
116°
115°
114°
113°
112°
111°
110°
45°
44°
43°
42°
MONTANA
YELLOWSTONE NATIONAL PARK
SHOSHONE L.
LEWIS L.
HEART L.
RESERVOIR SITE
JACKSON L.
RESERVOIR SITE
TETON PEAKS
W Y O M I N G
O R E G O N
I D A H O
N E V A D A
BAKER CITY
HUNTINGTON
WEISER
PAYETTE
Weiser River
PAYETTE L.
Malheur River
Boise
BOISE CITY
NAMPA
Snake River
MOUNTAIN HOME
Owyhee River
Bruneau River
Salmon River
Salmon Falls Cr.
Big Wood River
KETCHUM
HALEY
BELLEVUE
SHOSHONE
Big Lost River
KIMAMA CRATERS
BIG BUTTE
MINIDOKA
Goose Cr.
ALBION
Raft River
AMERICAN FALLS
POCATELLO
Blackfoot River
Bear River
MONTPELIER
EAGLE ROCK
S. Fork of Snake River
N. Fork of Snake River
REXBURG
SWAN VALLEY RESERVOIR SITE
Scale: 1/6,000,000
MAP
SOUTH IDAHO
NOTE. Shaded portion denotes irrigable land (in Snake River Valley only)

When irrigated it is estimated that it will be worth $75 per acre, making a property value of at least $35,000,000. The Idaho Mining and Irrigation Company, the capital stock whereof is largely owned in New York City, has constructed an important series of irrigation works. The chief one is known as the New York Canal. This canal in its first division is to be double in capacity to the great Erie Canal, the latter being but 70 feet wide at the top and only 7 feet deep. The Idaho "New York" Canal for 30 miles will be 12 feet deep and 81 feet wide, with a grade of 2 feet to the mile. The starting point is in a cañon 12 miles above Boise where the river emerges from the mountains. The lava bluffs on either side give the requisite solidity for the head-gate works. The first 12 miles will cost in all $230,000. The land to be irrigated there does not exceed 1,000 acres. The canal has been brought out on high lines, bringing under water it is asserted at least 450,000 acres. The Phyllis canal belonging to the same company is planned to supply water to some 35,000 acres. These figures are controverted by others. The total cost of the Idaho Company's works so far are not less than $1,100,000. It is assumed that besides the irrigated lands a large amount of hydraulic power will be accumulated, so that factories and mills can be established. The canal may also be used for floating lumber. The works are of the most substantial character and present some novel features, especially in the way of drawing the sediment off from the canal, destroying the silt therein, so as to prevent the ditches from being filled by sediment. The mode of gauging water for sale, introduced by Capt. A. D. Foote, C. E., will be utilized in these works. The cost per acre for the first year is to be $2.50, after which the cost will be 5 cents per miners' inch for each twenty-four hours.

Since these reports were made a considerable interest has been aroused by the striking of artesian water at Boise and Moscow. At the close of September, 1890, there were twelve artesian wells in operation 2 miles from Boise at an elevation of 180 feet above the town, and at an altitude of 2,280 feet above sea level. The last eight wells are 45 feet in depth and water was struck at 40 feet. Rising above the surface the daily flow is now estimated at 750,000 gallons. There are four other wells in the vicinity, a little deeper and with about the same proportionate volume. Another well is being sunk at Fort Boise but water in sufficient volume has not yet been reached. The town wells at Moscow, 3 in number, are about 90 feet deep with a bore of 2½ inch diameter, having a flow for the three wells of 56,000 gallons of water per hour. The flow of these wells named is over 1,300,000 gallons per 24 hours. Water can be obtained below the surface at a depth of from 50 to 100 feet. Quite a number of artesian wells in this county are being used for the irrigation of lawns, gardens, and orchards. At Boise the water companies owning the wells advertise to irrigate the orchards and vegetable gardens thereof. The evidence is abundant that in Idaho, as elsewhere in the arid region, there may be found a large supply of underground waters. The discussion of the past year has attracted close attention to this subject. An estimate made of the water supply in sight, before the Senate committee, is as follows:

	Cu. ft. per second.
Flow of Snake River (at Eagle Rock)	5,000
Flow of Salmon River (in Cassia County)	1,820
Flow of Boise River	6,000
Flow of Payette River	1,000
Flow of Weiser River	180
Flow of Big Wood River	154
Flow of Raft River	745

On the table lands, in the spring of the year, are many natural lakes or ponds; some of these are perennial, others having a depth of from 3 to 5 feet disappear, with the advance of the season, indicating that depth of evaporation and seepage for three months. From the last rivers the water runs right into the lava and keeps sinking. In the Big Lost River it runs down on the cañons and after awhile it is all exhausted. That whole country is one system of sub-storage. The water from Camas Creek, Bingham County, also loses itself in the desert and rises again in the range of lakes along the line of Idaho and Montana.

Value of ditches, etc., in several counties of Idaho.

[Per last Territorial report of Governor W. L. Shoup, 1889-90].

Counties.	Assessed value of improvements on lands.	Assessed value of patented lands.	Number of acres.	Assessed value of irrigating canals.	Assessed value of mining ditches.
Ada	$1, 229, 841	$841, 267	136, 800	$30, 125	....
Alturas	50, 550	27, 214	16, 886	....	$4, 027
Bingham	208, 595	325, 434	117, 148	†650, 000	....
Bear Lake	162, 300	100, 127	208, 330	*a*73, 500	....
Boise	64, 845	39, 725	10, 701	1, 100	51, 360
Cassia	86, 765	153, 710	48, 224	3, 528	....
Custer	196, 290	....	25, 780	8, 430	5, 996
Elmore	48, 385	49, 616	20, 360	370	5, 996
Idaho	95, 870	192, 673	97, 961	....	3, 900
Lemhi	170, 585	47, 719	12, 029	*e*40, 000	*e*50, 000
Logan	115, 037	107, 785	85, 364	1, 500	1, 000
Oneida	163, 831	212, 531	53, 132	21, 560	....
Owyhee	125. 510	54, 222	55, 628	15, 000	1, 850
Washington	92, 715	463, 520	48, 022	5, 400	3, 000
Total	2, 811, 119	2, 616, 543	926, 365	850, 513	127, 129

There are eight artesian wells at Boise, four serving that place, having 11 miles of water pipes.

Divide Idaho by counties, and we shall have the following concise statement of facts showing their relation to irrigation, present and perspective.

Ada County.—Every surface and nearly every spring that can be utilized for irrigation is now under surface. Outside of the Boise and Payette River systems, there are about 100 miles of small ditches. The large streams furnish the main supply for the farmer's use. At the beginning of 1890 there were 36 ditches, having a length of 308 miles, with 30 miner's inches of water taken from this stream. In all there are 62 complete ditches, having a total length of 408 miles, in this county. Two hundred and seven of these miles are impressed in three systems.

Alturas County.—There are 268,000 acres of arable land, of which 14,500 acres are arid and under ditch. Of the total area 21 per cent is estimated as reclaimable. Only 5.13 per cent are now under ditch. The county had, in January, 1890, 10 ditches, 18 miles in length with a carrying capacity of 1,700 miner inches.

Bear County.—This is one portion of the Mormon settled region. Small farms are the rule. Irrigated and under ditch are 21,500 acres; available for reclamation 40,000 acres; 35.5 per cent of the reclaimable land is now utilized, under the Mormon system of small farms and ditches. The average area of the farms will not exceed 7 acres. With a length of 206 miles, there are 69 canals.

Bingham County.—Also settled by the Mormons, has 284,750 acres irrigated and under ditch; 10 per cent of the reclaimable land is now irrigated. In all, 2,503,500 acres can be brought under cultivation. The ditch mileage is 517, divided into 86 primary canals and ditches.—A. D. Foote, C. E. of Boise, sends the following tables:

Bingham County, Idaho, 1890.

[Reported by A. D. Foote, C. E.]

Name of canal.	Source of water supply.	Locality.	Total length (miles).	Length, first section (miles).	Bottom width (feet).	Grade per mile (feet).	Length, second section (miles).	Bottom width (feet).	Grade per mile.	Remaining section (length).	Bottom width (feet).	Grade per mile).	Total cost.
Rexburg	Teton River	Bingham Co.	11	6	12	2½	5	8	5	6	16	4	$8,000
Westfield	...do	....do	7	2½	13	2½	2	8	5	2½	8	4	3,000
Fall River and Teton Canal.	Falls River	....do	10	2	30	5½	2	30	15	6	30	10	10,000
Teton	Teton River	....do	9	4	14	2½	5	10	2½	....	....	..	5,000
St. Anthony	Henry's Fork	....do	20	6	30	2½	6	20	7	8	10	7	12,000
Consolidated Farmers.	....do	....do	10	6	30	4	4	12	2½	....	....	...	6,000
Cedar Hollow and Foot Hills.	South Fork Snake	....do	25	13	40	7½	13	30	7½	....	....	...	....
Idaho	Snake River	....do	43½	12	40	1½	23	30	2	8½	30	6	75,000
Porter	....do	....do	9	9	30	2	....	....	....	....	....	...	50,000
La Belle	South Fork Snake	....do	5	5	25	....	....	....	....	....	....	...	16,000
Farmer's Friend	...do	....do	14	14	18	....	....	....	....	....	...	...	10,000
Eagle Rock and Willow Creek.	...do	....do	50	15	30	6	16	20	6	19	15	6	100,000

Name of canal.	Amount paid in cash.	Remainder paid in labor.		Amount it could be contracted for at present time.	Work begun in—	Work finished—	Water first used—	Amount water claimed* (miner's 4-inch inches, head).	Owned by—
		Men per day.	Teams per day.						
Rexburg	$1,000	$2.00	$4.00	$8,000	Mar., '83	June, '83	May, '83	5,000	Corporation.
Westfield	200	2.00	4.00	3,000	—— '85	May, '88	May, '88	2,500	Private parties.
Fall River and Teton Canal.	500	1.50	3.00	....	July, '89	—— '90	....	50,000	Corporation.
Teton	300	2.00	4.00	5,000	—— '83	—— '83	June, '83	5,000	Do.
St. Anthony	800	1.50	3.00	12,000	July, '88	May, '89	—— '89	20,000	Do.
Consolidated Farmers.	1,000	1.50	3.00	6,000	Oct., '88	—— '90	May, '90	5,000	Private parties.
Cedar Hollow and Foot Hills.	......	......	......	....	Sept., '88	....	....	50,000	Corporation.
Idaho	75,000	......	......	75,000	June, '89	—— '90	—— '90	100,000	Do.
Porter	50,000	......	......	25,000	—— '85	—— '86	—— '86	10,000	Do.
La Belle	4,000	2.00	4.00	15,000	June, '87	Unfinished.	—— '88	25,000	Do.
Farmer's Friend	3,000	2.00	4.00	10,000	—— '87	June, '90	Aug., '88	....	Do.
Eagle Rock and Willow Creek.	50,000	3.00	6.00	75,000	—— '80	—— ,90	—— '80	....	Do.

* Claim recorded in Blackfoot.

NOTE.—In addition to these canals the following works in Bingham County are under way in part belonging to the extensive system devised for storing and distributing the head waters of the Snake River. They are: Upper and Lower Liman canals, from south fork of Snake River, having a length of 14 miles (7 each); length of first section, 7 miles; width at bottom, 12 feet; grade per mile, 5 feet. Three canals (Texas Slough, Salem, Woodmansee) from Teton River; two of 10 miles each in first section, 20 feet in width, one of 27½ and the other 5 feet grade, the third canal having length of 3 miles, a width of 20 feet, and a grade of 2½ feet. Four canals from Falls River (Fall River, Anderson, Kern, and McBee), one of 12 miles, first section, 20 feet deep and 10-inch grade per mile; three having 3 miles, estimated, with 6 feet for one and 10 feet depth of the other two, and a grade of 2½ feet per mile., Three canals from Henry's Fork (Birch, Egin, and Mason), one of 6 miles, one of 15, and one of 3; having width of 15, 26 and 8 feet; two having grades of 2½ and one of 76.10. One from Leigh's Creek (Buckner Ridge) with 6 miles length, 12 feet width, and 10 feet grade per mile. Canon Creek and canal, 16 miles, 12 feet width, 5½ grade per mile.

Number of canals as reported	28
Mileage of canals as reported	3,221½
Total cost of twelve canals	$295,000
Total cost of twelve canals as reported, in cash (balance in labor at from $1.50 to $3 per day, according to Mormon usage)	$185,000
Amount of water claimed—	
In miner's inches per second as reported	322,500
Cubic feet	6,450
In gallons	41,573.5

Bingham County, Idaho, 1890—Continued.

Legal name of corporation or association.	Controlled by—	Officers in charge distribution.	No. shares ownership divided into.	Shares issued.	Remaining shares held by—	Par value shares.	Selling value shares,
Rexburg Irrigation Canal Co	Directors	Superintendent and water master.	2,000	800	Company.	$10.00	$10.00
Westfield Canal Co	do	Water master.	12	12		250.00	250.00
Fall River and Teton Canal Co	do	do	2,000	1,000	Company.	10.00	10.00
Teton Canal Co	do	do					
St. Anthony Canal Co	do	do				50.00	50.00
Consolidated Farmers Canal Co	do	do					
Cedar Hollow and Foothill Canal Co.	do	do	2,500	500	Company.	30.00	30.00
Idaho Canal Co	do	do	5,000	5,000		100.00	100.00
Porter Canal Co	do	do					
La Belle Irrigating Co	do	do	12,500	4,000	Company.	5.00	5.00
Farmer's Friend Canal Co	do	do					
Eagle Rock and Willow Creek Canal Co.	do	do	4,000	4,000		25.00	25.00
Total shares as reported			28,012	14,312			

Legal name of corporation or association.	Shares furnish water for—	Amount annual assessment, share.	Cash, or worked out.	Day work, 10 hours, man.	Day work, 10 hours, man and team.	Area of arable land under canal.	Area actually watered.	Area in alfalfa and clover.
	Acres.					*Acres.*	*Acres.*	*Acres.*
Rexburg Irrigation Canal Co	5	$1.00	Cash, 80 cts. balance.	$1.25	$4.00	5,000	2,000	400
Westfield Canal Co	200	20.00		1.25	4.00	2,400	600	200
Fall River and Teton Canal Co.	10	5.50		1.50	4.00	40,000	5,000	1,000
Teton Canal Co						2,000	1,500	300
St Anthony Canal Co	10	5.00		1.50	4.00	30,000	5,000	1,500
Consolidated Farmers Canal Co						5,000	2,000	500
Cedar Hollow and Foothill Canal Co.	10					125,000		
Idaho Canal Co	10					100,000	Few.	
Porter Canal Co						5,000	510	200
La Belle Irrigating Co	2	.50	Cash			4,000	800	200
Farmers' Friend Canal Co						15,000	3,100	500
Eagle Rock and Willow Creek Canal Co.	5	3.75		2.00	4.00	25,000	10,000	4,000
Total						358,400	22,570	8,800

Bingham County, Idaho, 1890—Continued.

Legal name of corporation or association.	Area in other hay, grasses.	Area in wheat, oats, etc.	Area in common vegetables.	Area in orchards.	Irrigation season begins.	Irrigation season ends.	
	Acres.	*Acres.*	*Acres.*	*Acres.*			
Rexburg Irrigation Canal Co.	150	1,000	400	50	Apr. 20	Oct. 1	From A. S. Anderson, Kaintuck, Aug. 30, 1890.
Westfield Canal Co	20	300	70	10	Apr. 20	Oct. 1	Do.
Fall River and Teton Canal Co.	1,000	2,500	400	100	Apr. 20	Oct. 1	From A. S. Anderson, Kaintuck, Aug. 28, 1890.
Teton Canal Co	100	900	140	60	Apr. 20	Oct. 1	Do.
St. Anthony Canal Co	100	1,000	1,400	100	Apr. 20	Oct. 1	Do.
Consolidated Farmers Canal Co.	400	1,000	80	20	Apr. 20	Oct. 1	Do.
Cedar Hollow and Foothill Canal Co.	......	......	......	......	....	....	From E. P. Henry, Eagle Rock, Aug. 31, 1890; not completed.
Idaho Canal Co	......	......	......	......	....	....	From Joseph A. Clark, Eagle Rock. Aug. 30, 1890.
Porter Canal Co	200	200	100	10	May 1	Sept. 15	Do.
La Belle Irrigating Co	200	300	90	10	May 1	Sept. 15	From W. H. B. Crow, Eagle Rock, Aug. 29, 1890.
Farmers' Friend Canal Co.	200	2,000	300	100	May 1	Sept. 15	Do.
Eagle Rock and Willow Creek Canal Co.	1,500	4,000	500	......	May 1	Sept. 15	From Joseph A. Clark, Eagle Rock, Aug. 30, 1890.
Total	3,820	13,200	3,480	460	....	....	

Boise County.—The total area irrigated or under ditch is 83,500 acres. It is claimed that 26,200 acres can be reclaimed by the supply of water in sight. There are in the county 20 ditches; total length, 60 miles.

Cache County.—Has under ditch and irrigated 82,000 acres; estimated as irrigable, from the valuable water supply, if stored, 655,000 acres. There are 298 farm canals and ditches, with a total length of 299 miles, a remarkable illustration of the small farm system of the Mormon population.

Custer County.—Has 24,000 acres irrigated and under ditch, and claims 446,000 acres as reclaimable. The ditches are all small and individual in character.

Elmore County.—There are 10,000 acres under ditch and irrigated; 230,000 acres can be reclaimed and served by the water supplies of the county. In this county there are 50 ditches with a total length of 25 miles.

Idaho County.—Irrigation is not generally used. Some small ditches for both farm and manufacturing purposes have been constructed. There are a considerable number of bored and driven wells within the county. They are used chiefly for stock and domestic purposes. The valley land, it is claimed, does not need irrigation. On the opposite side of the river, in Washington, water is raised by centrifugal pumps and distributed for irrigation purposes over the land, similar to those in use in Idaho County.

Kootenai County.—Is one of the northern sections of the Panhandle region. Very little irrigation is practiced in the southern portion of the county; it is considered unnecessary. The granite nature of the soil, however, precludes ditch construction to any great extent. It will probably be supplied by underflow sources.

Latah County.—Also belongs to the semihumid area of Idaho. The only irrigation practiced here at present is that involved in the use of artesian water for lawns, orchards, and garden purposes. There are probably between 100 and 200 low-pressure wells in the county, showing the possibility of obtaining a much larger supply.

Lemhi County.—Has 10,000 acres under ditch and irrigated. It claims 600,000 acres as irrigable. The ditch surface is confined at present to the valley lands of the Lemhi, Salmon, and the small lateral tributaries thereof. The length is 300 miles in 250 ditches.

Logan County.—Has reported 50,000 acres under ditch or irrigated, and claims 1,250,000 acres as reclaimable. The chief source of supply are the two Wood Rivers. The mileage of ditches in connection therewith is about 120; 140 miles of ditches have been constructed on the famous Kamas Prairie, which, with similar full systems, will make 300 miles in all.

Nez Perces.—There is only one ditch reported in this county, and the use of the water for irrigation is only incidental. A considerable supply can be obtained from phreatic sources.

Oneida County.—Reported 38,800 acres under ditch or irrigated, with 148,000 acres that can be reclaimed. Storage reservoirs are claimed as necessary for this region. A large canal project to carry water from the Bear River in Bingham County is also under consideration. There are 65 ditches, with a length of 100 miles.

Owyhee County.—Reported 21,300 acres in process of irrigation and under ditch, with a reclaimable area of 248,500 acres. There are 66 ditches of 153 miles in length within the county.

Washington County.—Reported 40,000 acres as under ditch or irrigated, and claims 500,000 acres as irrigable. The Weiser River supplies 270 farm ditches and one county ditch of 12 miles in length. There are 5 important canals in the neighborhood of the Weiser with a length of 40 miles, and its tributaries of about 80 miles. Its slopes cover nearly 15,000 acres. This is a great fruit region. Each occupied and cultivated homestead will have 5 acres devoted to fruit. The total length of Washington ditches will be not less than 290 miles.

The future of the State of Idaho, from an irrigation standpoint, is among the brightest within the arid domain. Its prospects warrant all the efforts that are being made, and its citizens are proving themselves among the most enterprising in this direction of the entire Northwest.

Of districts and enterprises in the State under the most active development during 1891, some reference is given, which while it does not cover all that deserves notice, presents those of which the office of irrigation inquiry has some definite data.

The Idaho Falls Canal is situated in Bingham County, Idaho, taken out of the Snake River, 22 miles northeast of Idaho Falls, is built in a southwesterly direction, extending to the Blackfoot River, making the canal 45 miles in length. The canal is 40 feet on the bottom, 3 feet deep, 2 feet slope, berme banks 3 feet, top banks 5, capacity 455 cubic feet per second. The first branch leaves the main canal 1¾ miles from head gate, and is 12 feet wide on the bottom, 2 feet deep, with a capacity of 140 cubic feet per second. The main ditch is completed 8 miles from head gate; first branch is completed 5 miles, with 26 miles of farm laterals; proof has been made on some 14,000 acres tributary to this first branch. The second branch will leave main canal 11 miles from head gate, and be 38 miles long, 16 feet on the bottom, 3 feet deep, 2 feet slope, berme banks 3 feet. Land tributary to main ditch and laterals, 57,000 acres. A large construction force has been constantly employed, and the managers expect to have their system completed in June, 1892.

The Great Western Canal system, comprising two canals, is in the same county, and is owned and operated by a construction company so named, with headquarters in Chicago. This system has a capacity of 640 cubic feet of water per second, and will furnish water for irrigating 115,000 acres of land. These two canals, one called the Great Western and the other Porter ditch. The former takes its water from the west bank of the Snake River, opposite Bear Island, 11 miles north of Idaho Falls, has head gate of solid masonry 100 feet wide, 71-foot openings for water, with foundation in the rock bottom of the river. A large dam is thrown across the river 1¼ miles below the head gate, raising the water to the surface. Directly above the dam is placed the second head gate that controls the water in the canal, consisting of eight gates 6 feet wide and 7 feet deep. This canal is 40 feet wide on the bottom with a capacity of 450 cubic feet per second; its total length south and west down the valley will be 58 miles. The Porter ditch takes its water from the Snake River, 2½ miles north of Idaho Falls, has a strong wooden head gate, is 25 feet wide on the bottom and has a capacity of 190 feet per second. It has been in use for five years, and main canal is 8 miles long with 30 miles of branches. The total number miles of completed ditches are: Main, 20 miles; branches, 40 miles; of farm laterals, 50 miles; delivering water in 1891, on 8,000 acres of land. It is intended to complete the system by October, 1892.

One of the most notable of the new irrigation systems now in progress is that under the management of the "Boise City and Nampa Irrigation, Land and Lumber Company," whose source of supply is the Boise River, the water for which is taken some distance below the dam of the Idaho Canal Company at a point 5 miles above Boise. The initial point of the extensive system now growing was made in the purchase of the "Ridenbaugh ditch," 9 miles long, and carrying a small volume of water taken from the Boise River, 5 miles above Boise. This, with the rights, was sold to the Idaho Central Canal and Land Company, who, considering it a poor investment, disposed of it to its present owners, who, eighteen months ago, organized under the name of the Boise and Nampa Irrigation, Land and Lumber Company, with a capital of $1,000,000. Taking this ditch as a basis, the system within a year has been extended into one of 100 miles of main and 153 miles of lateral ditches, which, with a chain of ten lakes and reservoirs for storage, completely cover the Boise and Deer Flat valleys, together with all the intervening table-lands. Without the construction of a dam at its point of diversion (which frequently involves an outlay of $100,000) the water comes from the Boise at the rate of 3½ feet per second, in a canal 45 feet wide at the top, 22 at the bottom, and 6 feet deep, taking a third of the river's volume at low water. The main ditch is 12 miles long, two branches going through the Boise Valley, each 25 miles in length, and one, the Nampa branch, extending 41 miles through the Deer Flat Valley.

There was a good deal of practical skill and sagacity displayed in the selection of the point at which the water is tapped. The old ditch has been enlarged and extended, while new highland canals of considerable size have been constructed along the ridges, so as to insure every advantage of gravity, and, what is still more important, to warrant the utilization of a number of natural lake beds and depressions along the canal routes which, at comparatively moderate cost, can be utilized for reservoirs. Two of such basins are in operation; one at Nampa, the point of railroad junction on the Oregon Short Line with the branch road to Boise, 18 miles distant; the other is 3 miles distant from Nampa. One of the proposed lakes will serve 30,000 acres, and the others cover areas of from 5,000 to 15,000 acres each. The engineering importance of this enterprise is found in the adoption of this plan of open tableland reservoirs.

The section under the Nampa system is even more favorably located for such a purpose than that of northeast New Mexico, to which references have elsewhere been made. On the whole the climate is more genial, while the whole of the Boise Valley is under control of the "Chinook" or warm winter winds of the Pacific northwest. Without attempt to proclaim any theories or advocate a special system, the personal observation and close study of the special agent in charge leads distinctly to the conclusion that American enterprise is developing in connection with such irrigation works as those already operated on the Maxwell Grant, in New Mexico, the system under organization and construction at Nampa and in the Boise Valley, and the very boldly devised and executed works along the Bear River, in North Utah (Cache County), with others that are projected, methods of utilizing natural conditions for water storage, conservation and management that are practically new in character and promise large results in both safety and service, as well as in the great economy of construction and administration they will achieve. Mountain and high altitude channel storage holds great danger within their lines; storage of the table-land character under review can, with reasonable strength of embankments, be readily made safe, while the advantages for service, etc., are very much greater. There would necessarily be under such a system, as that of the Nampa Company, a much less degree of construction cost attached to river, cañon, or mountain reservoir system, requiring heavy masonry or earth and rubble dams, and there must also be provided a costly system of service ways, head gates, flumes, etc., capable of resisting flood tendencies. The economy of the table-land system of reservoirs appears to be in the fact that the mountain streams and sources by which they are to be supplied can be conducted to the reservoirs, one on the open plain at a comparatively small cost, and with works of a simple character. The silt carried down may be handled easier and cheaper if necessary by means of settling basins, from which the cleared water can be drawn to other reservoirs. Again, the need of obtaining a sufficient fall of gravity pressure compels the adoption of high ridge lines, and consequently brings a larger area "under ditch" and earlier reclamation. All of these points are well exemplified in the Nampa system, which will bear close study by irrigation organizers and constructors. Another point as to this section is seen in the possibility of easy drainage. Much of the area to be served by the system is underlaid at a short depth from the alluvial surface by a larger of hard volcanic tufa, from a few inches to a couple of feet in thickness. In the making of their canals the company have often been obliged to blast through this thin strata. It was pointed out that its existence indicated the possibility of great economy of water and the early need of systematic drainage. The surface soil will quickly fill up, and the surplus will run off swiftly. The contours of the principal area to be served are such (except the Deer Flat section, which is open mesa or plainsland having an easy fall to the west) as to insure the collection of drainage waters, and their return to the irrigation channels at a small cost and by means of low-lying open ditches in which the drainage can readily be collected.

The Boise and Fayette valleys are excellent fruit-growing sections; probably second only to the coast counties of California below San Francisco Bay for the production of prunes. The soil of these valleys is a decomposed lava and very rich in all the requirements of vigorous plant life. All the cereals, clover, timothy, and alfalfa, and nearly all kinds of temperate fruits, like apples, pears, peaches, prunes, as well as all the smaller fruits are grown abundantly here, and roots grow to perfection. Watermelons attain prodigious size, and the right conditions exist for the successful culture of the hop vine.

Farms and orchards in the Boise and Fayette valleys and on Deer Flat are in proof of the remarkably productive power of southwest Idaho, and in all reasonable probability of the adjacent sections of eastern Oregon. With the Missoula and Bitter Root valleys in Montana, and the Walla Walla and other sections of eastern Washington, the whole of southwest Idaho will become a region of great horticultural importance. The Nampa Company served during 1891 about 13,000 acres, of which nearly 10,000 are under the old Ridenbaugh ditch. In 1892, this service will be nearly or quite double in extent.

The increase in horticultural activity in this section is shown by the statement made to the special agent that one nursery firm had sold within the year 80,000 trees, prunes, pears, plums, etc. On every hand the evidences of activity were visible and the movement along the northwest routes surpasses in activity and extent even that of the southwest. As land is held at more moderate rates and there are still large areas of public land to be settled upon, the general immigration shows a younger and hardier class, one to whom "climate" has not been a paramount condition.

There are a large number of other enterprises in Idaho, showing the active interest felt in agricultural reclamation there. Among these is an enterprise of importance, which is to derive its support from the Snake River. The lands to be irrigated are located in Logan and Cassia counties, in the central and southern part of the State, and its construction will add a new and large area to the field of irrigation, for it would surely be followed by other efforts. The river dam, by which the needed water is to be diverted, is built at Mendoca, Idaho, near the railroad crossing and just above the point where begins the great lava bed, through which the Snake River for so long a distance cuts a turbulent pathway. The main ditch is to be 45 miles in length, and 85,000 acres lie on the north side of the river and 15,000 acres on the south side. The significant engineering point in this work is the fall of the river, which is 7 feet per mile above the dam and 30 below it. The proposed canal begins at the dam site at an elevation of 37 feet below low-water line, and follows the rim of the lava bed all the way to Starr Ferry. The amount of land that can be irrigated on the south side will increase in the ratio of 1,000 acres to every 1 foot in the height of the dam. In order to secure this increase, the south side canal will have to be moved to higher lines than they are now run upon. On the north side of the river nothing will be gained by increasing the height of the dam, for here the lava shuts off all the increase; a 30-foot dam covers all the land below the rim of the lava. The variation between high and low water is about 12 feet. The length of the dam between the abutments is 527 feet. The apron will be built in 12 by 12 timbers. The cost of the dam is $133,150, and the canal on the north side is 32 miles long to the point where it enters the river again. On the south side it will be 12 miles long, and three-quarters of this will be excavated through lava. The ditch is 40 feet wide and 10 feet deep at the dam. The cost is estimated as follows:

Canal	$215,000
Dam	133,150
	348,150
Engineer expenses	56,000

In addition to the 100,000 acres to be irrigated, there are, under the projected canals, 225,000 acres that only require a cut of a mile and a half through the mountains to irrigate.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers to circulars received by this office:

ADA COUNTY.

Caldwell (post-office), Howard Sebree (September, 1891):

Has cleared and improved farm of 300 acres, irrigated by water from a canal 23 miles long, with capacity of 20,000 cubic inches to serve 20,000 acres; estimates cost per acre of clearing and preparing sage-brush land for irrigation and cultivation at $3 (his system does not require plowing). One dollar and fifty cents per cubic inch is the average rental of water per annum. One half of a cubic inch per acre is sufficient after land is once irrigated. Perpetual water rights are assessed 25 cents per cubic inch for annual repairs.

Products successfully raised by irrigation and yield per acre of same: Wheat, 30 to 50 bushels; corn, 40 bushels; oats, 40 to 80 bushels; all other small grain; apples, peaches, pears, prunes, plums, cherries, and other fruits, etc.

Falks Store (post-office), Edson Bishop (September, 1891):

Water supply: Payette River.

Irrigation works: Ten miles main ditch; numerous laterals; main ditch 8 feet wide on bottom, 14 feet wide on top. One main headgate; about thirty small ones; five waste gates.

Cost per mile of ditches: Main, $1,000; laterals, $200. Cost per acre from $3 to $10. Cost per acre for annual maintenance and repairs, $1 to $2.

Average cost per acre for preparing land for cultivation by irrigation: For sage-brush land, to clear, grub, level, and seed it down, nearly $20.

Cost of water supply to user per acre, $2 (annual rental, $2).

Area under ditch, 2,000 acres; under cultivation, 200 acres.

Chief products: Wheat, oats, hay, sugar cane, hops, fruit, potatoes, beets, etc.

Average annual yield per acre: Wheat, 20 bushels; oats, 50 bushels; hay, 5 tons; potatoes, 100 to 250 bushels; all other crops not produced sufficiently to estimate.

Boise City (post-office), A. D. Foote (September, 1891):

Idaho Mining and Irrigation Company (system not completed, but it is proposed to include storage of about 250,000 acre-feet of water; one canal (Phillis) completed; others only partially); water supply, Boise River.

Area under ditch, 25,000 acres; under cultivation, 2,000 acres

Mileage and size of ditches, 55 miles; 24 feet at top, 12 feet at bottom, 6 feet deep; grade, 2 feet per mile; one head gate; reservoirs not yet built.

Cost per mile of ditch, $3,000; average cost per acre, $4.

Average cost per acre for annual maintenance and repairs, $2 (including interest on cost of works).

Average cost per acre for preparing land for cultivation under irrigation: Clearing, $2; plowing, $2; fencing, $1; ditches on land, $1; total, $6.50.

Cost of water supply to user per acre, $2.50; annual rental cost, $2.50.

Chief products: Hay, cereals, potatoes, and fruit.

Value of annual product per acre, $25.

Boise City (post-office), Joseph Perrault (September, 1891):

Water supply: Walling Canal, Boise River; appropriation, 100,000 inches; oldest water right on river built in 1864.

Works: 7 miles main canal; first mile, 60 feet on top, 50 feet on bottom; other 6 miles, 10 feet on bottom, 15 feet on top; 2 head gates.

Area under ditch, Boise City and 2,000 acres of land outside, all of which is under cultivation (extension proposed to reach 50,000 acres).

Cost per mile of ditch, about $7,000; cost per acre, about $5.

Average cost per acre for preparing land for cultivation under irrigation, $5; grazing, $2.50.

Average cost per acre for annual maintenance and repairs, about $1.

Average cost per acre of water supply to user, $4.

Annual rental, for lots 50 feet by 122 feet, $5 per season.

Staple products under irrigation, wheat, rye, oats, barley, corn, potatoes, alfalfa, timothy, clover, apples, pears, plums, prunes, peaches, and small fruits.

Average annual yield per acre: Wheat, 40 bushels; rye, 25 bushels; oats, 50 bushels; corn, 60 bushels; potatoes, 400 bushels; alfalfa, 6 tons; timothy, 2 tons; clover, 6 tons.

Nampa (post-office) J. M. Jones (September, 1891):

Boise City and Nampa Irrigation, Land, and Lumber Company.
Water supply, Boise River; area under ditch, 100,000 to 150,000 acres; under cultivation, 10,000 acres (first year after completion of canal).
Irrigation works: Total mileage of ditches, 250; 103 miles of main ditches; at head gate, 22 feet at bottom; 38 feet wide at water level; 3 main ditches; 16 feet wide on bottom; 4 main head gates.
Number and area of reservoirs: 5 reservoirs—(No. 1) 15 acres; (No. 2) 120 acres, 16 feet average depth, dam 420 feet; (No. 3) 50 acres, average depth 9 feet, dam 600 feet; (No. 4) 320 acres, average 16 feet deep, dam 400 feet (this lake is 2 miles long); (No. 5) 230 acres, 12 feet deep, dam 200 feet long.
Cost per mile of ditches: Main ditch, $4,000; laterals, $200 to $2,000; cost of reservoirs, etc., $20,000; cost per acre for farm laterals, 50 cents.
Average cost per acre for preparing land for cultivation: For clearing sage brush, $3; plowing, $1.50.
Average cost per acre for maintenance and repairs, 15 cents (with perpetual water right); annual rental per acre per annum, $1.50 (without water right).
Products under irrigation: Wheat, oats, barley, rye, alfalfa, clover, timothy, potatoes, and other vegetables—apples, pears, prunes, peaches, plums, quinces, berries, etc.
Average yield of products per acre: Wheat, 25 bushels; oats, 50 bushels; barley, 40 bushels.

Payette (post-office), The Payette Nursery and Fruit Farm (per W. G. Whitney, December 9, 1891):

Water supply, Payette River; irrigation works in neighborhood.
Three ditches: (1st) Settlers' Ditch, 16 feet wide on bottom, 20 feet top, 7 miles long; (2d) Stevenson Ditch, 8 feet bottom, 12 feet top, 15 miles long; (3d) Lower Payette Ditch, 12 feet bottom, 16 feet top, 8 miles long. A head gate for each ditch; no dams on rivers; several new ditches under construction; cost per mile, about $3,000 (cost depends upon the size of ditch and nature of soil, etc.).
Area under ditch, 80,000 acres; under cultivation, 10,000 acres.
Cost of water supply to user per acre, $1.50; annual rental cost, $1.
Average cost per acre for preparing land for cultivation (under irrigation), $10.
Average cost per acre for ditches, etc., $1.
Average cost per acre for annual maintenance and repairs, about 25 cents.
Products under irrigation and yield per acre: Alfalfa, 9 tons; clover, 8 tons; wheat, 40 bushels; oats, 80 bushels; potatoes, 500 bushels. All kinds of fruits yield abundantly. Average value of product per acre, $40 net profit.

Payette (post-office), A. B. Moss & Bro. and Payette Valley Bank (September, 1891):

Lower Payette Ditch (appropriation, 100,000 inches).
Water supply, Payette River; area under ditch, 8,000 acres; under cultivation, 4,000 to 5,000 acres.
Works: Eight miles of main ditch, 12 feet on bottom, 20 feet on top, 4 feet deep. (Proposed extension of 13 miles.) Two main headgates, 40 lateral gates; no other works.
Cost per mile of main ditch, about $2,000; average cost per acre for main ditch, $2; for laterals, $1; cost per acre for annual maintenance and repairs, $1.
Average cost per acre for preparing land for cultivation under irrigation, $10.
Cost of water supply to user per acre, $1. (All users of water own shares in ditch.)
Chief products under irrigation: Hay, fruits, grain, and vegetables.
Estimated value of products per acre: Hay, $30; fruits, $300; grain, $25; vegetables, $100.

Nampa (post-office), James A. McGee, president of board of trade (January 20, 1892), in an address to the board, stated as follows:

The enterprises we have started have been the means of increasing the value of over 200,000 acres of land between Boise and Snake River from $1.25 to at least $10 per acre without water, and on an average of at least $25 with water; or from a value of $250,000 to $2,000,000 without water, and to a value of $5,000,000 with water.

The assessed value of the whole county has been increased 200 per cent.

BINGHAM COUNTY.

Blackfoot (post-office), D. M. Cappo (September, 1891):

Corbett Slough Ditch. Water supply, Snake River. Area under ditch, 5,000 acres; under cultivation, 3,000 acres.

Works: Twelve miles of main ditch. Capacity, 7,000 inches. Size, 22 feet at top, 14 feet at bottom, at its head, and lessens gradually to 6 feet at the terminus. No reservoirs. Two headgates. Laterals or private ditches taken out along the whole length of main ditch.
Cost of ditch per mile, about $350; cost per acre, about $1.50.
Average cost per acre for preparing land for cultivation under irrigation, from $5 to $15; for grazing, about half of this.
Cost per acre for annual maintenance and repairs, about 10 cents.
Cost per acre of water supply to user, $2.
Chief products: Hay, grain, potatoes, and other vegetables, fruit of various kinds, melons, etc.
Value of products per acre: Estimates that "crops costing $5 to $8 per acre will bring from $20 to $25 per acre."

[Area under cultivation under this ditch will be doubled next year.]

L. E. Hall (Salt Lake City, Utah), "President Idaho Canal Company:"

Water supply, Snake River. Area under ditch, 25,000 acres (estimated); under cultivation, 1,000 acres.
Irrigation works: Twelve miles main canal, 40 feet on bottom; two branches, 23 miles and 7 miles long, 30 feet each on bottom. Loose rock dam at headgate, 15 rods long, 3 feet high. One main headgate composed of 7 separate gates, each 8 feet wide, giving 56 feet space for opening for water; headgate of solid masonry laid in cement, rock piers; 6 waste gates; 6 large culverts under canal; other works, flumes, bridges, etc.
Cost per mile of canal: Main line, $5,000; branches, $1,500.
Cost of headgate, $6,000; culverts, $4,000; waste gates, $2,000; bridges, $3,000; right of way, $5,000. Canal not completed. Cost given as far as constructed.
Average cost per acre of works, ditches, etc., $5.
Average cost per acre for preparing land for cultivation under irrigation, $5.
Average cost for annual maintenance and repairs, 75 cents.
Cost of water supply to user per acre, "not determined; 12½ cents at present."
Annual rental cost, 75 cents at present.
Chief products: Wheat, oats, barley, hay, and potatoes.

[Data for county generally, compiled from answered circulars sent to Senator F. C. Dubois, Martin Patrie, T. J. Smith, and others.]

Water supply, Snake and Blackfoot rivers and tributaries.
Area under ditch, variously reported; generally estimated that 75 per cent of agricultural area of county is under ditches or canals either constructed or in progress of construction, and about 40 per cent under cultivation.
Irrigation works: Three large canals under construction, Market Lake and Butte Canal, Idaho Canal, and Great Western Canal; from 75 to 150 miles main canal from 25 to 50 feet on bottom; very many smaller or private ditches; 8 headgates (main), smaller ones numberless.
Cost per mile of canals or ditches, from $200 to $10,000; cost per acre, from $3 to $8.
Average cost per acre for preparing land for cultivation under irrigation, about $6.
Cost per acre for annual maintenance and repairs, about 25 cents to 75 cents.
Cost per acre of water supply to user, from $3 to $8; annual rental cost, from 25 cents to $1 per acre.
Chief products: Wheat, oats, barley, some corn, alfalfa, timothy, potatoes, prunes, pears, apples, cherries, strawberries, and all small fruits.
Average annual yield per acre: Wheat, 25 to 35 bushels; oats, 40 to 50 bushels; potatoes, 200 to 300 bushels; alfalfa, 5 tons; timothy, 2 tons.

Eagle Rock (post-office), John F. Shelley, secretary and treasurer, Eagle Rock Willow Creek Water Company (November, 1891):

Water supply, Snake River. Area under ditch about 40,000 acres; under cultivation, about 10,000 acres.
Irrigation works: 50 miles main canals and laterals, two main canals, 20 feet and 30 feet on bottom, respectively; two headgates in river.
Total cost of canal, etc., $100,000; annual rental cost of water, 50 cents per acre.
Average cost per acre for preparing land for cultivation under irrigation, $5; for irrigation works, ditches, etc., $4; for annual maintenance and repairs, about 50 cents.
Chief products: Wheat, oats, alfalfa, timothy and blue grass hay, potatoes, and other vegetables.
Yield per acre: Grain, about 40 bushels; potatoes, about 300 bushels.

Idaho Falls (post-office), secretary Great Western Canal Company:

Water supply, Snake River, main channel. Area under ditch, 50,000; under cultivation, perhaps 500 acres.

Irrigation works: 50 miles ditch, 30 feet on bottom (except for the first mile from the head, which is 40 feet), 45 feet at top; two headgates; no reservoirs or dams.
Cost per mile of ditch, about $3,000; cost per acre, about $3.
Average cost per acre for preparation of land for cultivation under irrigation, about $5; cost for annual maintenance and repairs per acre, about 25 cents.
Products: Wheat, rye, oats, barley, potatoes, timothy, and alfalfa.
Estimated value of annual product per acre, $20 net.

CASSIA COUNTY.

Basin (post-office), A. B. Roberts (September 19, 1891):

Has 960 acres under ditch 500 acres under cultivation.
Water supply, Willow Creek; capacity, 300 inches (mountain stream, fed by melted snow).
Irrigation works, 2 miles of ditch, 2 feet wide at bottom; 1 headgate (to guard against floods); a distributing gate; "ditches in neighborhood generally made by plowing a few furrows, then running a V-shaped scraper through it."
Cost per mile of ditch, $2.50; average cost per acre, 8 to 10 cents; average cost per acre for preparing land for cultivation (under irrigation), about $2 (including leveling); for grazing no irrigation is used.
Cost of water supply to user per acre, 5 cents; annual repairs, $1 (on whole ditch).
Staple products and yield per acre: Alfalfa, 6 tons (2 tons for each cutting); wheat, 30 bushels; oats, 35 bushels; barley, 35 bushels; potatoes, 250 bushels.
Water service estimated at less than 10 inches for 100 acres. The waters of all the small brooks and springs is appropriated; dams and reservoirs needed for irrigation on a proper scale.

[The Spring Basin Water Company, of this vicinity, have 4,500 acres under ditch, about 1,000 acres under cultivation; cost for annual repairs not more than $20; for distribution, $150 annually—wages of water master.]

Thatcher (post-office), George Chapin (September, 1891):

Water supply, Goose Creek; capacity, June 1, 7,000 inches; September 1, 1,000 inches; area under ditch, 1,000 acres; under cultivation, 360 acres.
Irrigation works, main canal, 14 miles long; average width, 8 feet; depth, 3 feet; fall, 7 feet per mile; capacity, 1,000 inches; headgates, 1 for main canal and 1 for each lateral; no other works.
Average cost per mile of main canal, $100.
Average cost per acre of irrigation works, ditches, etc., in vicinity, $1.
Average cost per acre for annual maintenance and repairs, 25 cents.
Average cost per acre for preparing land for cultivation under irrigation, $3.
Average cost per acre of water to user, 50 cents (per annum).
Staple products: Wheat, oats, barley, rye, potatoes, and all garden vegetables raised in Northern States, alfalfa and timothy hay, large and small fruit.
Average product per acre: Wheat, 30 bushels; oats, 45 bushels; barley, 40 bushels; rye, 25 bushels; potatoes, 250 bushels; alfalfa, 6 tons; timothy, 3 tons.

ELMORE COUNTY.

Mountain House (post-office), C. P. Oliver (September, 1891):

Water supply for irrigation is pure spring water coming out of granite formation; no extended system of irrigation in neighborhood; ditches from spring, which carries about 160 inches water; 3 headgates; has 100 acres under ditch; 60 acres under cultivation; area under ditch by other neighborhood systems, 300 acres.
Average cost per acre for preparing land for cultivation (under irrigation), $10.
Average cost per acre for preparing land for grazing (under cultivation), $5.
Average cost per acre for irrigation works, ditches, etc., $7.50 (for large tracts.)
Average cost per acre for annual maintenance and repairs, about $1.
Staple products: Hay, grain, vegetables, and all kind of fruit raised outside of tropical climate.
Estimated yield per acre and value: Hay, 6 tons; grain, 60 bushels; potatoes, 400 bushels; fruit yield worth about $150 per acre (except peaches, which are worth much more).

[Geo. P. Hall (of Mountain House, this county) states that "this vicinity is a good field for developing artesian water."]

LOGAN COUNTY.

Bellevue (post office), John Hailey (September, 1891):

Has 100 acres under cultivation with irrigation; about 2,000 acres under ditch in neighborhood.

Average cost for preparing land for cultivation under irrigation: For clearing land having growth of sage brush, willows, etc., about $5 per acre; fencing, 50 cents per rod.

Average cost per acre for irrigation works, ditches, etc., about $5.

Average cost per acre for annual maintenance and repairs, $1.50.

Staple products: Wheat, oats, barley, alfalfa, timothy, and native grasses, potatoes, cabbage, and other garden vegetables in common use.

Yield per acre and value of same: Wheat, 25 bushels, 75 cents per bushel; oats, 35 bushels, 50 cents per bushel; barley, 30 bushels, 60 cents per bushel; potatoes, 150 bushels, 40 cents per bushel; alfalfa, 4 tons, $5 per ton; timothy, 2 tons, $8 per ton; native grasses, 1 ton, $6.

OWYHEE COUNTY.

Silver City (post-office), L. J. Pritchard (September 19, 1891):

Water supply of neighborhood, creeks having generally an abundance of water until June or July each year.

Irrigation works: Ditches averaging 1 mile in length, 2 feet wide on bottom, depth varying, but running as much as 9 feet deep; dams about 5 feet high; head gates for each ditch and lateral; all ditches, etc., owned by water users. (No reservoirs.)

Cost per mile of ditches, about $120; cost of dams, about $30.

Cost of water supply to user per acre, $5.

Average cost per acre for preparing land for cultivation under irrigation: For clearing land of sagebrush, greasewood, etc., $4; plowing, leveling, etc., $6; total, $10.

Average cost per acre of ditches, etc., about $5.

Average cost per acre for annual maintenance and repairs, about $1.50.

Products, yield per acre, and value: Wheat, 30 bushels; barley, 40 bushels; oats, 45 bushels; hay (principally alfalfa), 7 tons; vegetables, and fruit; average value of crop per acre at present prices, about $30.

Average area under each ditch, 60 acres; under cultivation, 30 acres.

WASHINGTON COUNTY.

Weiser (post-office), T. C. Galloway (September, 1891):

Water supply: Weiser River, abundant supply in early spring months; fails generally by July 1 each year.

Irrigation works: Canal (or ditch) 17 miles in length; width, 16 feet on bottom at upper end, 5 feet at lower end; dam, 4 feet high; 2 head gates, 7 waste gates, 1 flush gate, 4 flumes, each 100 feet long; capacity of ditch (1891) 3,000 inches; 40 per cent lost by seepage, etc.

Cost per mile of irrigation works, $2,000 (not yet completed).

Average cost per acre of works, ditches, etc., from $1 to $10.

Average cost per acre of preparing land for cultivation (under irrigation): For clearing out sagebrush, etc., $2; plowing, $2; leveling, $6.

Average cost per acre for annual maintenance and repairs, about $1.

Area under ditch by this or neighborhood system, 5,000 acres; under cultivation, 2,000 acres.

Chief products: Wheat, corn, oats, barley, alfalfa, sorghum, potatoes, beans, and other vegetables and fruits.

Yield per acre: Grain, about 30 bushels; hay, 1 to 5 tons; potatoes, 300 to 400 bushels; beans, 500 bushels.

[Water sold for $1 per acre under this system.]

CENSUS FIGURES FOR STATE.

The United States Census Office (Bulletin 157) reports for this State (Mr. F. H. Newell) as follows for the year 1889:

Number of counties	18
Number of irrigators	4,323
Total acreage irregated and in crops	217,005
Average size of farms in acres	50
Average value of products per acres	$12.93

MONTANA.

This State lies between the meridians 104 to 116 degrees of longitude west from Greenwich, and the parallels of north latitude 45 degrees, 15 minutes to 49 degrees. Its average breadth is 275 miles and its greatest length by northeast and southwest is 540 miles. It contains 145,776 square miles or 92,016,000 acres of land. It is bounded on the north by British America, on the east by North and South Dakota, on the west by Idaho, and on the south by Wyoming and Idaho. In area, Montana is the third largest State in the Union, being surpassed in extent only by Texas and California. One-third of its extent consists of high mountain ranges which form the northern portion of the Rocky Mountains, and in which lie the sources of the Missouri River system. The western slope of these ranges is marked by large tributaries of the Columbia flowing to the Pacific Ocean. Approaching Montana from the eastward the land gradually rises about 8 feet to the mile, until Livingstone, in the center of the State and at the eastern base of the Belt Mountains, is reached. The average altitude of the State is not over 3,000 feet. The higher ranges will rise from 6,000 to 7,000 feet above sea level, and the loftiest peak in the State obtains an altitude of 11,000 feet.

Montana is among the best watered States on the continent, its river system being of the largest order, comprising the Upper Missouri basin formed by the confluence of the Gallatin, Madison, and Jefferson rivers, all rising in the higher ranges of the northern Rockies. The Upper Missouri has a course of 500 miles within the limits of the State. The Yellowstone, its principal tributary, has a similar course and carries a body of water equal to that of the leading stream. On the north, the chief feeders of the Missouri are the Milk, the Marias, and the Sun rivers, and on the south, the Yellowstone and Musselshell. The principal tributaries of the Yellowstone are the Powder, Elk, and Big Horn rivers. West of the Rockies the drainage runs into the Clark fork of the Columbia. In the extreme northwest the Kootenai and the Bitter Root drain that important section, making two of the most valuable valley regions in the State. Numerous other tributaries are confluent on either side of the range with these larger streams. Everywhere they form fertile valleys, broad mesas, and high table or plateau areas, making of Montana one of the most important pastoral regions. Though the streams and rivers are numerous, the hydrography of Montana is very simple in character. On the east it is all comprised in the Missouri basin, and on the west in that of the Columbia. There are many mountain lakes and basins, which must form at no distant day available reservoirs for the great storage supplies that will be required in the reclamation of some 20,000,000 or 25,000,000 acres of arable land. The hydrology of Montana is such as to warrant the statement that a larger proportion of its great area can be brought under irrigation, and made to produce in abundance all the grains, grasses, fruits, and vegetables of the temperate zone than is the case with any other section of the arid region.

The largest mountain lake is known as the Flathead, a beautiful body of water, 30 miles long by 10 wide.

The chief characteristic of Montana in regard to climate is its dry and bracing atmosphere. Like all arid regions, the temperature is better than its latitude would indicate. Towards the northwest the lowering of the mountain ranges admit of the passage of the famous "Chinook" wind, bringing in its passage from the Pacific the warm breath of the Japanese current. Heavy snows very often disappear in one night under the influence of the "chinook." The thermometer's range is about the same in winter as that of northern Iowa and Wisconsin, but the weather is much more endurable, and the average is warmer. The summer heat, though warm, is never excessive, and the nights are always cool. The sheltered mountain valleys in summer and winter are more endurable than the open plains, especially to the eastward. The low range mountains which permit the passage over their summits of the moisture-laden winds of the Pacific Ocean act as condensers, so that their summits in winter are laden with heavy snows, and in summer gather rain, with the full force of the eastward-moving moisture. A considerable proportion of Montana, especially in the north, is claimed to be semihumid in character, owing to the early summer rains, but even there the benefits of irrigation in making positive security for agriculture is fully acknowledged, and large enterprises of that character are under way. In the central and southern portions of the State, as well as eastward through the great open valleys of the Yellowstone and Upper Missouri, irrigation is a direct necessity. Its application insures crops, according to the testimony before the Senate Committee, of from three to ten times in value, in quality, and in quantity, of products of same character raised in the central and eastern States.

The higher mountain region is well timbered, and when going westward, the trees belong chiefly to the Pacific coast varieties and the evergreen family. They are usually of a great size and valuable for merchantable lumber. On the eastern slopes, while the trees in the timber belt grow to a great height and density, the trunks are not usually large. Several varieties of the pine comprise the great body of this timber. Along the Missouri and the Yellowstone, with their principal tributaries, are found large amounts of cottonwood, box elder, and ash. The table and bench lands are treeless. The timbered area is estimated at about 36,000 square miles.

The soils of Montana are generally of the best quality, largely formed of the mountain débris, being both granitic and volcanic in character. They range from heavy clay to light sand, but consist principally of a dark or chocolate-colored loam. The best soil is found on the *mesa* or bench land just above the valleys and rising to the base of the mountain ranges. Probably no better wheat land exists on the continent than these same mountain plains. Wheat has been cultivated for twenty years past, yielding from 30 to 40 bushels per acre, and showing no diminution. The grain is always heavy and the yield is astonishing. In the Gallatin Valley, where farming has been carried on for the longest period, 40 bushels to the acre has been a usual crop since settlement began. In the Little Belt Basin oats are raised weighing 45 pounds to the bushel and producing 85 bushels to the acre.

In the valley of the Yellowstone at Glendive, Miles City, and Billings, it was stated, in testimony taken by the Senate committee, that from Livingstone to the mouth of the Yellowstone the valley area alone embraces 765,000 acres of reclaimable land. Corn will produce 30 bushels to the acre; wheat, 45 to 50; potatoes, 450 bushels; alfalfa grows 6 tons to the acre yearly; and that all the small berries and fruit trees of the temperate zone can be grown successfully. With irrigation all crops would be secure, and their yield largely increased. With a proper storage system it is assumed, and on reasonable grounds, that about 8,000,000 acres of bench lands could be reclaimed by means of high-line ditches. The general feeling in eastern Montana is favorable to that form of irrigation enterprise. Nearly the whole of the higher table lands can be made available for the cultivation of root crops and of forage plants, thereby insuring a rapid change from cattle ranch to cattle farm. The Gallatin Valley has been cultivated for more than twenty years, producing large crops continually. The testimony shows that an average crop per acre of potatoes would be 400 bushels; of oats, from 30 to 60 bushels; of wheat, 40 bushels; of barley, from 50 to 100 bushels, or an average of 75 to the acre. This is the result of irrigation. Without irrigation the yield is two-thirds less per acre. Irrigation begins in the last of May or the first of June. In this valley the irrigation enterprises have heretofore been of the ordinary community character, projected and constructed by the farmers themselves. Large enterprises are now under way, which will probably greatly increase the acreage under ditch and rapidly advance the economy of water use. In the Judith Basin, the Teton and Sun River valleys, a considerable area has been brought under cultivation. The bench lands of the two rivers are from 400 to 500 feet above the valley bottom, and it has a slope towards the Missouri of 100 feet in 6 miles. The soil is warm, with sand enough in it for fertility, underlaid with gravel so as to insure good subsoil drainage; the frosts on these lands are never early in the fall or late in the spring. The blue-joint grass, peculiar to Montana since population went in and cultivation begun, grows abundantly there and makes the finest hay in the State. Mr. H. M. Wilson, engineer of the U. S. Geological Survey, estimates that there are 700,000 acres of excellent land that can be readily reclaimed. Thirty-five to 40 bushels of wheat are produced to the acre; also, 4 tons of blue-joint hay and 3 of timothy can be raised to the acre. Fruits and berries grow rapidly and well.

The Society of Civil Engineers in a report to the Senate committee, declared that 1,000,000 acres or but one-ninetieth part of the State is now irrigated and cultivated. The possible area of reclamation was estimated at 20,000,000 acres. The area reclaimable without a system of general storage would not exceed 3,000,000 acres. Such a system of storage in their opinion can not be constructed without the aid of State or national government. The high table lands having a general altitude of 3,000 feet are largely reclaimable; but the problem of water storage and distribution for such lands involves great expenditure and a high degree of engineering skill and enterprise.

The underflow and artesian water problems have heretofore attracted but little attention in Montana. Such wells as have been bored in the Yellowstone Valley are of considerable depth and their pressure and flow are not great, but everywhere may be found at moderate depths a supply of negative artesian water, rising nearly or quite to the surface, and even now forming a valuable supply for stock and domestic purposes. The enormous volume of precipitation that falls upon the ranges of Montana does not all, it is evident, find its way through the surface channels to the great Mississippi Valley and thence into the Gulf. The indications all point to a considerable absorption of this precipitation by the earth itself. This phreatic supply will on further investigation be found both large and accessible.

Messrs. W. W. De Lacy and W. C. Childs have given interesting statements from the standpoint of underground supply. Mr. De Lacy said that where gravel was found underlying the surface coil there was a great tendency of the mountain streams to disappear as they reached the bench lands. He said :

> A great many of our streams are running dry alternately; that is to say, there will be a stream of water for a mile or two, then it will sink, and then it will reappear. When that is the case, they are generally on a loose gravel bed. I think the reason of that is the water percolates through the gravel and disappears, and then for some reason comes up again. * * * The water is generally found at bed rock, and its depth from the surface differs with the depth of the bed rock. In a great many of the streams that are apparently dry I think that reservoirs could be built by sinking a dam down to bed rock. Frequently you will see a stream that is in a little cañon of perhaps 100 yards or so, and the stream may be dried up at either end of it, though having water above. I think if a well were put down to bed rock the water would be forced up and there would be a reservoir, and a very convenient one.

Mr. Childs, of Helena, is a farmer on a large scale and of recognized ability. In the sections where cultivation was claimed to be successful without irrigation, he has said that water would be found within a foot or two of the surface. "In my belief," said Mr. Childs, "if you dig 7 feet anywhere you will find standing water. Such water is found on the bench lands. It seems to be a sheet of water underlying the whole bench land area. It does not rise when tapped, but appears to remain at the same level continuously."

Mr. Childs described the manner in which he utilized a natural spring by boring immediately behind its outflow, thus increasing the same. The natural flow was about 5 inches of water. On sinking the bore to the depth of 160 feet he has obtained a flow of 200 gallons per minute. A 3-inch pipe was put in and the flow continues at 13 inches above the ground. Mr. Childs declared that he knew it to be true that flowing water could be found beneath the beds of so-called dry streams. At the time of the committee's visit he was engaged in digging a bed rock drain in a channel 2,000 feet above the stream that supplies his ditch. The evidence showed there had been a loss of water by sinking of 25 miners' inches. From the results then achieved he expected to obtain a flow of 150 inches of bed-rock water, a supply fully as great as that of the normal surface flow. In Mr. Childs's opinion, then, this is true generally of mountain streams.

Mr. G. C. Swallow, inspector of mines, described a stream in the Judith Mountains known as the "Dry Wolf." In a portion of its course it flows 500 and for several miles 800 miners' inches of water. This water then disappears. Mr. Swallow believes that it could be restored to the surface by means of a bed-rock dam. Evidence could be multiplied on this point, but it is not necessary as the general topography is abundant proof of the probability of finding phreatic waters all over the State of Montana, and at a reasonable depth below the surface. It remains true, however, that the storage-reservoir system will finally be the one on which Montana must largely depend.

Of the sixteen counties in the State of Montana nearly all of them have considerable areas of land that could be made available by irrigation for agriculture. Dawson County, in the extreme northeast, having an area of 25,650 square miles, with but 50,000 acres now under cultivation, claims the possible reclamation, by means of water in sight, of some 4,000,000 acres. The county is watered both by the Upper Missouri and Yellowstone River systems. The latter stream passes through the southeast corner of the county, and most of the cultivated area lies in the valley thereof. At Glendive there are four ditch systems having about 60,000 acres under them. There are five wells in the vicinity of Glendive of considerable depths, the water of which rises nearly to the surface; it is then raised by windmills and used for stock and domestic purposes. It is estimated that 4,000,000 acres can be reclaimed in this county. North of the Yellowstone Valley there is no cultivation, except small patches for ranch purposes, until you reach the Milk River Valley. The Upper Missouri flows generally within cañons from Fort Benton, until it leaves the State at Fort Buford. The Milk River Valley, now being opened by railroads, is considered to be an excellent agricultural region. Water is obtainable from the streams and by means of underflow, the water plane being but a few feet below the surface. Accurate data as to the mileage of irrigating ditch is not obtainable, because in most cases they are simply small farm works of which no record is made. The Glendive works are supplied by water from Spring, Cane, and Fox creeks, and of the four irrigation works begun in that vicinity the main canal is 4½ miles in length, with 5 miles of lateral ditches, four dams, four head gates and two weirs. Its cost was $2,500. Many springs are utilized for garden irrigation.

Custer County, south of Dawson, and occupying the balance of the plains section of Montana, has an area of 32,300 square miles. It contains, also, the Crow Indian and Cheyenne reservations. Considerable activity in irrigation is seen in the neighborhood of Miles City. Nearly 100 miles of main canal are in operation, divided among some thirty different systems. The lateral or farm canals will have a length of 125 miles. There are thirty-five to forty dams, and the same number of head gates. One ditch, 20 miles in length, cost $100,000. The total cost of irrigation works is estimated at over $200,000, serving about 100,000 acres of land. On the Tongue River a canal has been constructed serving 16,000 acres of land at a cost of $60,000. Two steam pumps have been erected at Miles City, on the banks of the Yellowstone, and are now used to lift and distribute water for irrigation purposes. The crops raised are principally hay, oats, corn, potatoes, and garden vegetables. The largest area is laid down to grass and the making of hay. The cost of service is $1 per acre. Irrigated land ranges in value from $35 to $50 per acre, unimproved land, without water, from $5 to $7. Small berries and fruit trees grow well, and several score acres are now under cultivation. The valley of the Yellowstone within this county comprises at least 400,000 acres of reclaimable land. With the bench-lands and table-lands 3,000,000 acres can be put under ditch and cultivated. The area of reclaimable land within the Crow Reservation, which is also in this county, is estimated at 1,500,000 acres. This is watered by the Yellowstone and its southern branches. There are twenty-four artesian wells within a radius of 15 miles of Miles City. Their depths range from 150 to 500 feet with bores of from 1½ to 3 inches. They flow above the surface with considerable pressure. About 300 acres are now irrigated by the water of these wells in parcels of from 2 to 25 acres each. Water can be found without flow at a depth of about 50 feet, and it is easily obtainable upon the mesa or bench lands. Over 100 wells of this character are in operation within the same radius as the artesian wells referred to. Windmills are used for pumping purposes. A considerable quantity of the water from both classes of wells is used for hay lands, but the main use is for domestic and stock purposes. The first artesian well was sunk in 1884 and still flows with undiminished pressure. Springs are largely utilized for garden and grass land.

Yellowstone County, to the north of the river, has an area of 2,390 square miles. It is estimated that 500,000 acres can be supplied from the Yellowstone and Musselshell. The bench land between the two streams lies from 200 to 300 feet above the valley, and the fall to the eastward is such as to render the taking out of water by high-line canals a work of easy engineering. In 1889 there were five large enterprises under way, with a length of 70 miles. The area then irrigated was about 20,000 acres. One of the ditches has been extended 17 miles and is now 27 miles in length. By another work, 25 miles in length, 50,000 acres were under ditch in 1890. Water can be obtained at from 15 to 20 feet below the surface, and stock is generally supplied by such wells. The soil of this county is quite rich, and the levels are such as to render it easily irrigated by gravity. Nothing can be grown without irrigation, and water is needed wherever crops are raised. Wheat yields from 25 to 40 bushels per acre, oats from 50 to 70, and potatoes from 300 to 400 bushels.

Choteau County, in the extreme northern part of the State, and embracing the head waters of the Upper Missouri and Milk rivers, is now developing a considerable area of irrigated land by means of canals supplied by the Teton and Sun rivers. Fifty thousand acres are now estimated as under ditch and cultivation, and 5,000,000 is given as the limit of the reclaimable land. The valley of the Milk River, in the extreme north, forms a valuable body of agricultural land. It has been advertised widely as cultivatable without irrigation, but settlers who have gone on do not find that to be the fact. Indeed it can not be too clearly borne in mind that within the arid region all land to be fit for cultivation must have access to water either by artificial application or from natural subirrigation sources. Throughout this region, wherever necessity has compelled experiment, phreatic waters have been reached at a depth of from 5 to 20 feet below the surface. The principal irrigation enterprise in the southern part of Choteau County, and in connection with Cascade County, is the Sun River Canal and its branches. This is located at its head in Choteau County, and is expected to furnish an irrigation supply for 276,480 acres lying between the Teton and Sun rivers, north and south, and the Missouri and Rocky Mountains, east and west. In illustration of the farming value of northern Montana the following statement is given:

> R. P. Menefee, a prominent farmer, reports in 1889 the sowing of 5,665 pounds of wheat and the thrashing out of 5,515 bushels, weighing 209,580 pounds, or very nearly 37 pounds harvested to each pound sown. In 1890 Mr. Menefee reported 5,600 pounds of oats sown, the harvest yielding, when thrashed, 5,318 bushels, or 186,130 pounds; that is not quite 37 pounds return to each pound sown.

The works in progress in the section of which Great Falls is the business center show the irrigation demands of a region so far north. The Teton Canal is 18 feet wide at bottom, 25 feet at top, carrying 4 feet of water, has its source at the base of the mountains, on the north fork of Sun River, and runs east over high prairie land between the two streams. The completed Teton Canal branch is fed by that river, 2 miles from base of the Rocky Mountains. It runs east through a plateau known as Teton Lake Basin, thence 6 miles to head of Big Muddy Creek, using it as a water bed for several miles, thence by a lateral ditch 25 miles long, with twenty sublaterals covering over 40 miles in length, supplying a large tract from Choteau to Sun River, west of Great Falls in Cascade County.

Probably the most important branch is that being constructed in the latter county, having Benton Lake for a reservoir. This is 7 miles long and from 3 to 5 miles wide, and contains a great body of water. An abundant supply is insured, as the unfailing Teton River can through the canal so named be easily turned into the lake. This is tapped by a cut 1¼ miles long, and 45 feet deep; 500 feet of this cut was "sluiced" out in one week by means of a 40-horse power engine, pumping 500 gallons per minute. From the mouth of this cut two canals are being constructed, 20 miles of which are now dug, and which when completed will be 40 miles in length and be feeders for over 60 miles of lateral ditches; all will be completed for irrigation next season.

Cascade County, lying south of the center of Choteau County, shows great activity in irrigation, as will be seen by the works in progress there. Its area is 2,570 square miles. There is under ditch and irrigated some 50,000 acres. The reclaimable area is estimated at 600,000 acres. Over 100 miles of main ditch are now in operation in the county. This county is a point of great interest, owing to the appearance, in the neighborhood of Great Falls, of huge outcroppings of the Dakota sandstone. The foothills of the Rocky Mountains trend to the northwest and throughout Cascade and Choteau Counties are from 8° to 10° of longitude farther west than is elsewhere the case along the whole range. The appearance of the Dakota sandstone outcroppings at Great Falls is regarded by Department geologists as a positive proof of the conclusion which they have reached, that the vast artesian basin of the Dakotas and eastern Montana is supplied mainly by the drainage of the Rocky Mountains. The measurements made in 1891 by Chief Engineer Edwin S. Nettleton, of streams and springs above Great Falls, and of the river below them, show a great loss of flow between the two points, clearly illustrating the disappearance of a large surface supply by absorption in the sandstone at this point.

Canals now constructed have cost $500,000, and, including laterals, have a length of nearly 500 miles. The following are some of the leading works: Cascade Land Company, main ditch, 45 miles, 12 to 16 feet wide at top, carries 3,000 miner's inches, and will irrigate 3,000 acres. Sun River works, 12 miles long, cost $2,000 per mile, carries 3,000 inches, and irrigates 3,000 acres. The Crown Butte Canal, 26 miles in length, cost $3,000 per mile, carries 25,000 inches, will irrigate 210,000 acres, and has one reservoir, costing $25,000. Chestnut Valley ditch is 12 miles in length, and carries 15,000 inches. There are two other ditches, one 5 and the other 7 miles long, and several score of small farm and neighborhood and farm ditches. Three large projects are now under survey and are to be constructed during 1892.

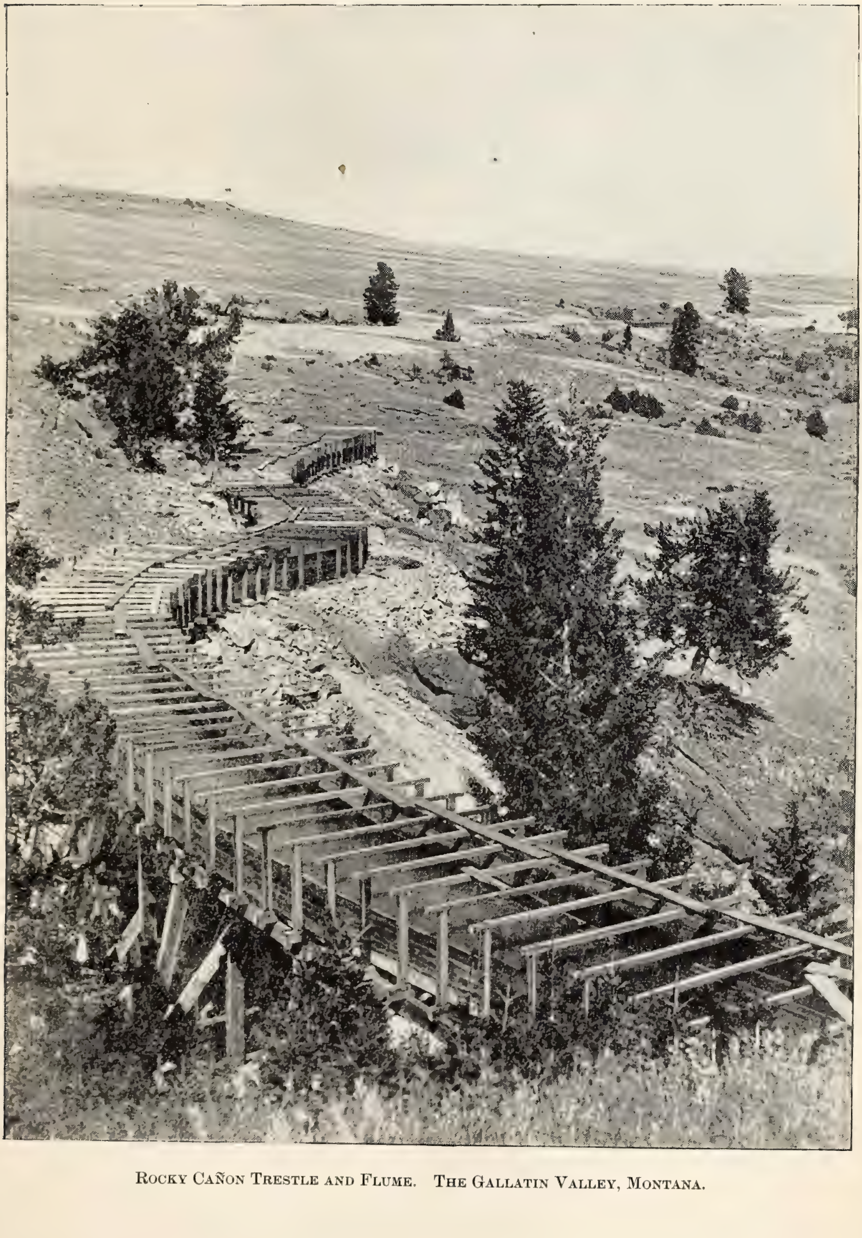
Fergus and Meagher Counties in the central and eastern part of the State embrace large areas of cultivatable land, the waters for whose reclamation will be supplied from the tributaries of the Upper Missouri and the Musselshell. Fergus County has an area of 7,415 square miles; Meagher County, one of 1,760 square miles. It is claimed that 150,000 acres are now under fence and ditch in Fergus County and 30,000 acres in Meagher. The famous Judith Basin lies within the borders of Fergus County. It is a region of excellent agricultural capacity. No large irrigation enterprise is found in either county. The ditches are mainly small affairs taken out by individual farmers from the many mountain streams that abound therein. The reclaimable area is put at 2,000,000 acres.

Park County, to the south of Meagher and north of the Yellowstone National Park, has an area of 4,740 square miles. About 15,000 acres are under fence and ditch, cultivated by means of irrigation. The surface of the county is mountainous. The principal industry is mining. The Yellowstone Valley contains the largest proportion of irrigable lands, and there are numerous small valleys that can be brought under irrigation. It is claimed that 500,000 acres can be so utilized.

Gallatin County is now the most important agricultural region in Montana. Over 100,000 acres are under ditch and cultivated. Water therefor is supplied by the East and West Gallatin rivers, Middle Creek and its branches, on the east, and from the west by the Madison and Jefferson rivers. Gallatin Valley is well cultivated. Irrigation works are usually small, having been constructed by individual farmers. Several large canals are now in process of construction, and the facilities for distribution will be greatly extended during 1891. The East and West Gallatin canal, 25 miles in length, carries 8,000 miners' inches. The Middle Creek ditch carries 2,000 miners' inches. Other canals now in construction are taking water from the West Gallatin and Madison rivers. Underground water is obtainable by wells at no great depth. It is estimated that 400,000 acres will be reclaimed. The cost of irrigation is about $1 per acre annually. The foothills of the mountains surrounding the Gallatin Valley will afford an excellent locality for the cultivation of the fruits of the temperate zone. Bozeman and the region around it have been under continuous cultivation for nearly thirty years, and the grain and root crops continue now as heavy as when the land was first cultivated.

The most important irrigation area within the borders of Montana is that embraced within the Gallatin Valley, of which Bozeman on the Northern Pacific Railroad, is the thriving center. Mr. C. A. Gregory, a former citizen of Chicago, who has had considerable irrigation experience in New Mexico and is now resident in the Gallatin Valley, sends the office of irrigation inquiry in response to questions sent him, quite a full statement of irrigation conditions here. Mr. Gregory's intelligence, his knowledge and personal reliability in such matters is known to the special agent in charge, and there is no hesitation in presenting here what Mr. Gregory says under date of December 10, 1891:

> You ask many questions and the details of these would require months of investigation to answer quite accurately. I will give you an honest summary, the result of observation and inquiry, and mainly in the order of your inquiry. I do not spare pains to answer you. I despair to give you perfect figures, but I will at least avoid the error of overstatement, even to gratify the pride of this valley, rich enough and prosperous enough as it is, when fairly stated.
>
> The mileage of private farm ditches in the Gallatin Valley, *i. e.*, the cultivable portion of Gallatin County, Mont., it would be exceedingly difficult to give. Some attempt, however, must be made in order that a stranger to the situation may form a tolerably correct idea of the extent of irrigation in this locality.
>
> Hundreds of miles of private farm ditches exist. These come out of some twenty or more creeks and streams, including the East Gallatin River, a small feeder to the West Gallatin, which latter is a strong mountain stream of heavy fall to the mile and of large capacity of flowage, elsewhere stated; so that portions of more than a dozen townships are supplied, more or less, with irrigation facilities, and some thoroughly. This valley may be roughly said to be four townships wide by five townships long, mainly sloping, with undulations from south to north, with counter slopes from the circumference; everywhere surrounded by mountainous country, which is indented with deep cuts or cañons on the easterly and southerly borders, from which issue permanently-flowing streams. From all these streams, except the West Gallatin River, every drop of water is conducted into small and large private farm ditches, and utilized for irrigation. From the West Gallatin River, also, many ditches are taken for farm use; and from this river alone are taken out the three large canals owned by incorporated companies, named in order of time of construction, the West Gallatin Canal Company, the West Gallatin Irrigation Company, and the Excelsior Canal Company, elsewhere further described.
>
> By far the greater part of the water of this river runs to waste. It is many times in its flowage the volume of all the water taken into its tapping ditches.



Rocky Cañon Trestle and Flume. The Gallatin Valley, Montana.

There are no reservoirs of water in this valley from which conserved waters are drawn. Up the Bozeman Cañon there is Mystic Lake, some 14 miles from Bozeman, some 2,000 feet in height above this valley, where a dam 22 feet high is now being built to hold backwater, to be run down the natural channel of great and rapid fall, and then to be drawn off into ditches for foothill and bench land irrigation. The capacity of this pond may be understood from its size, about 1 mile long by one-half mile wide, and great depth may be secured.

The only land companies are the Manhattan Malting Company and the West Gallatin Irrigation Company, the latter constructing a large canal to supply water mainly to its own lands and grantees of its land, and still owning some 25,000 acres; the former owning 160 acres in town-site at Manhattan and some 10,000 acres for its own farming purposes, mainly for the cultivation of barley.

The West Gallatin Canal Company's ditch is 20 miles long, cost said to be about $60,000; built about three years ago; taken out of the east side of the West Gallatin River, well up to the cañon; carries about 8,000 inches, it is said; built with inexpensive headgate and wing sieve dam of no great cost.

The Excelsior Canal Company's ditch is 12 miles long; built in 1890–'91; cost about $40,000, as estimated, and built by syndicate of farm owners under it, supplying water to its stockholders only; carries about 8,000 inches, it is stated; built with slight structure of headgate and no dam.

The largest and most costly canal is that of the West Gallatin Irrigation Company, constructed 1890–'91, and at present some 24 miles in length, on a high line to cover bench lands; taken out of the west side of the West Gallatin River; still in process of extension in length.

In this connection it is not important to state the area cultivated under these canals separately. Under the two first-named canals the total capacity of the ditches is required for the ground under them, and such land is already mostly in cultivation; under the last-named ditch the lands are mainly new and unbroken, and are just brought into such relation to water as to be cultivable. There lie under this ditch, as it may be extended, 60,000 acres, being more than the ditch has capacity to supply with water.

With caution held out that an estimate must be considered something of a guess, we should say that under great and little ditches there are about 50,000 acres in cultivation.

The auditor's report for Montana for 1890 gives the number of ranches in Gallatin County at 460, and the acreage in ranches in Gallatin County as 127,684 acres, and the ranches fenced as 115,374 acres. No scrutiny is made in these returns into the number of acres plowed. The acreage and the number of ranches have increased considerably since such figures were made up, and these figures are returns for assessment purposes only, and include railroad lands cultivated or uncultivated in the county. Much of such lands may not be cultivated. Such return is no index of what area is cultivated; let us go, therefore, to crop returns. The crop returns in auditor's report are not to be relied upon as coming up to the magnitude of area or yield per acre. We know individually of one tract of 1,200 acres now in cultivation, not embraced in 1890 year returns; we know of several tracts of 100 acres and upwards recently brought under the plow, not in such estimates. Fifty thousand acres are assumed as proximately the area in cultivation. We may see if this is tolerably correct by crop return. If you allow an average of 50 bushels to the acre in all kinds of grain, we shall have 2,500,000 bushels of grain, so that I think 50,000 acres a high acreage to state as cultivated, wheat, barley, and oats being the main crops; then consider the hay ranches worked upon, and not the natural grass ranches, and the vegetable and small fruit crops, and we may assume a yield of $1,250,000 in value. There are 35 thrashing machines here. These may be estimated as thrashing 60,000 bushels each on the average—certainly this is high enough to state it. This gives 2,100,000 bushels.

The average price of the three staples I place at an assumed figure, which I am advised is fair, and from this I get $1,250,000 as a year's yield in value. Any discrepancy in this result is certainly made up by considering hay and vegetables as included.

I furnish you a map of the Gallatin valley, and on it I place the three large canals and some of the lesser canal and marginal ditches, etc. To mark all the ditches would be to run out tortuous lines from every creek and river as thick as branches and their twigs from the main stem of a tree. A great fertile expanse, gridironed with circumfluent lines of ditches, bright and golden in harvest time with grain, and hay meadows in green for relief, and after harvest thick with stubble as a plush carpet is with its short, upreared filaments, is not an overdrawn picture of this valley.

Barley is great in yield and supreme in quality here; oats triumph in weight and measure to the acre, and wheat yield is as high in average as in any known region. You ask for the price of water. Water is not retailed here, but the price as understood by the canal companies is $2 per statutory inch as measured in accordance with the statutes of Montana—a poor method of measurement. This is a reasonable price.

The Gallatin valley is not alone the oldest cultivated valley, but it has been irrigated to a considerable degree. The average yield for a number of years (not less than twelve or fifteen) is as follows, and that, too, without any other fertilizer except water:

Wheat, per acre	bushels	35 to 60
Oats, per acre	do	50 to 90
Rye, per acre	do	40 to 60
Barley, per acre	do	35 to 60
Potatoes, per acre	do	300 to 500
Hay, per acre	tons	2 to 3

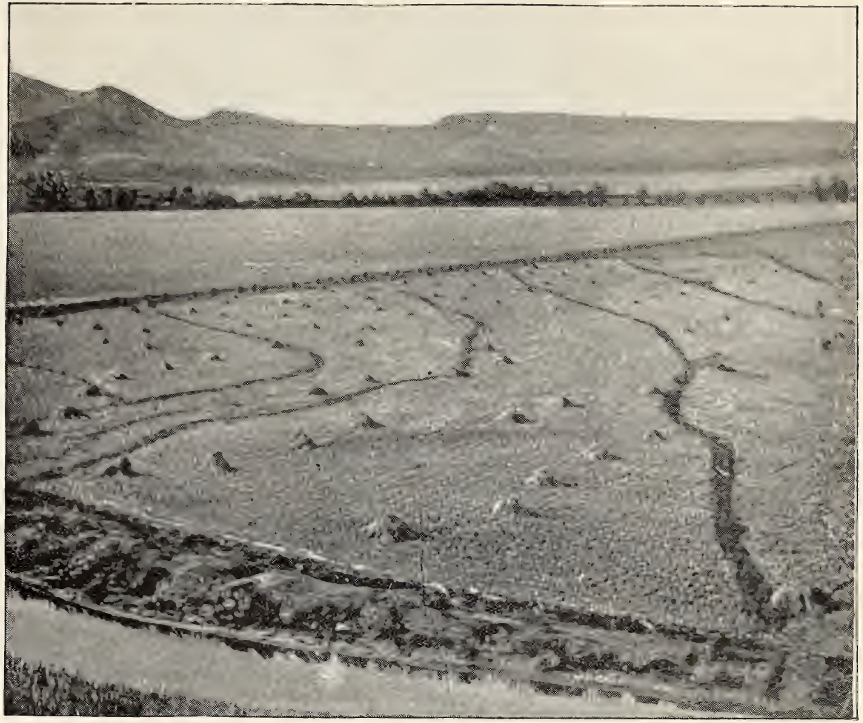
The annexed table refers to production during 1890, and will bear examination:

Name of farmer.	No. of acres.	Crop.	Total yield.	Yield per acre.
S. B. Cope	6¼	Wheat, bushels	401	63⅓
Richard Blum	32	do	137½	43⅓
E. A. Selleck	8	do	398½	50
Rev. Mr. Bird	10	do	450	45
D. A. Kughen	47½	do	2, 517½	53
Howell & Etheridge	160	do	6, 950	43½
J. A. Howes	180	do	6, 270	35
John Wilcox	97	Oats, bushels	4, 100	42
L. W. Ours	25	do	1, 926	77
F. Endres	30	Barley, bushels	1, 760	38⅔
C. Bressier	40	Timothy, tons	65	1⅝
John Hanson	1½	Potatoes, bushels	400	266⅔
Charles Anceny	150	Alfalfa, tons	650	4⅓

Madison County, to the north of Brigham, in Idaho, with Gallatin, is the oldest-settled section of the new State. Irrigation is an absolute necessity for agriculture. The area of the county is 5,440 square miles. There are about 100,000 acres now under ditch, of which about one-third is cultivated to cereals and roots. Half a million acres, it is estimated, can be reclaimed. The water supplies are furnished by the Madison, Jefferson, and Ruby rivers. No large works have yet been constructed, all the ditches being small farm affairs. A great many mining ditches have been utilized for irrigation purposes in this county as well as those to the north of it lying within the Rockies.

Jefferson County, to the north of Madison, contains 2,060 square miles. The reclaimable area is estimated at 250,000 acres, and 25,000 acres are now under ditch and fence. The county is watered by Prickley Pear, McClellan, Beaver, Crow, and Hot Springs creeks, north and east, and by Boulder, White Tailed Deer, and Pipestone creeks on the south. Two ditches in Crow Valley have a capacity of 870 miners' inches. The area of land irrigated could be increased threefold by the supply of water now in sight, with due care of water and by proper works. In illustration of the value of irrigation in this high, mountain region, a report of the Boulder Valley Ditch, Milling, and Stock Company, organized 1875, shows that the enterprise began with one settler and 240 acres. There are now 1,000 settlers cultivating 4,800 acres. Before settlement the value of lands was $2.50 per acre. Its present value, improved with water supply, is $300; unimproved, $50 to $75 per acre. Land has no selling value without water. The duty of water is stated to be as low as 5 miners' inches per acre. The cost is $1.25 per annum. The crops grown are wheat, oats, barley, potatoes, cabbage, and other vegetables. Production per acre under irrigation is fully double that in the humid States.

Lewis and Clarke County, centrally located in the mountains, has



Irrigation by Checks, Gallatin Valley, Montana.

considerable irrigable area, with about 50,000 acres inclosed and under ditch and cultivation. There is estimated to be in the basins of Prickly Pear, Ten Mile, Seven Mile, and Sun rivers, with their tributaries, a large area of arable land that needs water to make it valuable. The entire area of the county is 1,769 square miles, of which 627 are valley and mesa land. Ditches take up all of the water flow from Seven Mile and Silver Creek. From the natural flow, 6 per cent of the Prickly Pear basin can be irrigated. There are thousands of acres in the Sun River basin, within this county, which could be reclaimed, if water was found and stored. Four per cent of this area is now under ditch. In Prickly Pear Valley, 6,000 acres are now cultivated. The Helena Ditch in this valley has a capacity of 1,000 miners' inches. Florence Canal, 23 miles long and nearly finished, irrigates about 15,000 acres. Another canal supplies 2,000 miners' inches. The Flat Creek Canal is 4½ miles long. The entire length of irrigation ditches in the county is about 100 miles.

Silver Bow County, 760 square miles in area and 5,000 feet above sea level, is devoted almost entirely to mining. It is rugged and mountainous. It is estimated that 40,000 acres could be reclaimed. The area under cultivation is small. Irrigated land is assessed at $100 per acre and sells at $150; nonirrigated sells at $5 per acre. There are many mining ditches in the Silver Bow Basin, which furnish water for small areas of arable land and could supply more. Some discussion has been had in this county over the practicability of obtaining artesian water. Under present knowledge the judgment is generally against its availability.

Beyond the range are found the two counties of Beaver Head and Missoula, occupying the north and south portion of the western flanks of the continental divide and receiving the benefit of the warm and moisture-laden passage winds from the North Pacific Ocean. The plants and timber of the North Pacific slope are found in this section of Montana. The trees are large and of the varieties known to the Pacific northwest. The precipitation is considerable and, but for the summer failure, would be sufficient for most agricultural needs. The southwest county, Beaver Head, has an area of 3,740 square miles. In 1889 and 1890 from 80,000 to 90,000 acres of meadow land were inclosed for flooding purposes. This area could be increased to 250,000. Beaver Head County is watered by Big Hole and Beaver Head Rivers, with their principal branches, Grasshopper, Rattlesnake, and Red Rock creeks. The valleys are low and narrow and the soil is alkaline in character. The bench or mesa lands are of prime quality, the soil being of rich loam, which when irrigated produces with great abundance. The artificial application of water is absolutely necessary. There were in 1889 three organized irrigation companies taking water from the Beaver Head River, and a large number of small farm and private ditches. Some activity has been manifested in 1890 looking to improved facilities and larger irrigation works.

Missoula County, the extreme northwest section of Montana, with an area of 9,580 square miles, embraces a large proportion of the best fruit land within the State. It will be the richest horticultural section. In 1889, 150,000 acres were reported as inclosed, under ditch, or cultivated. The total reclaimable area is estimated as 600,000 acres, but it is probably very much larger if water can be found for the service thereof. The streams by which the county is drained and served are branches of the Columbia system. The Bitter Root Valley, 35 miles in length and about 12 wide, with an average elevation of 3,000 feet, is admirably adapted for fruit culture. This is shown by the orchard region around Missoula City. The west side of this valley is well watered by mountain streams. The east side presents the appearance of an unbroken table land, cut by very few water courses, and requiring for its reclamation the storage of water. The entire valley contains a large area of first-rate arable lands. The orchards seen at Missoula in the early fall of the year when the fruit is ripe make a scene worth traveling many miles to witness. Universally the trees are so heavily laden as to require large props to sustain the weight of the ripening fruit on their branches. Fine agricultural lands are found in the valleys of the Missoula, Hell Gate, Flathead, Blackfoot, and other streams. The Flathead Indians have for many generations raised fine crops, and under the instructions of the Jesuit priests, who have been their teachers, are among the best farmers of their race. The Bitter Root Valley land requires, it is claimed, 1 inch of water per acre, running continuously for a few days at a time, and for two or three times during the growing season. On the west side of the Bitter Root there are a large number of small farm ditches, estimated at a total of 50 miles in length. Some twenty larger ditches have a mileage of 75 miles. They carry from 200 to 300 inches of water. With an improved irrigation system and greater economy of water nearly a million acres might be reclaimed, one-fourth of which would be valuable fruit land. Wheat produces 20 to 60 bushels, oats 30 to 110, pease 20 to 80, and corn 40 to 50 bushels per acre. Potatoes will average 350 bushels, and grow so large that they weigh from 3 to 4½ pounds each. All vegetables and fruits of the temperate zone grow here in the utmost luxuriance.

Recent irrigation enterprises in Montana are the Fort Belknap enterprises by which, in connection with two others, 73 miles of ditches will be in part constructed. The area to be reclaimed will not be less than 20,000 acres; a ditch irrigating 5,000 acres between the South Mocassin and Judith rivers, in Fergus County, has been completed and is now in operation. The ditch is 16 feet wide on top, 12 feet on the bottom, and 30 inches deep, and between 8 and 9 miles in length. It taps Warm Springs Creek a short distance below the Horsehoe Bar ranch, and crosses a number of coulees, necessitating the construction of wooden fluming, which, at a distance, resembles a narrow-gauge railroad.

In the Smith River Valley a considerable storage reservoir has been created by the damming up of Lake Creek by private parties, who have secured thereby water sufficient for the irrigation of several thousand acres. These enterprises are referred to because they are typical of a large number in progress over the arid region, details of which have not been obtained, but of which enough is known to warrant the conviction that apart from the larger corporation progress, the progress of reclamation works is now as rapid as desirable.

The promise of Montana as an irrigable region is of the greatest significance and value. The estimate presented by its Society of Civil Engineers of 20,000,000 reclaimable acres is under rather than over the mark. A great deal has got to be learned as to the area of service and the economy of use in the waters that will make the lands fertile. Its two leading industries, mining and stock raising, have sometimes been esteemed as indifferent to the growth of farming and the advantages of irrigation. All this is rapidly changing and great progress may be looked for in Montana.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers received to circulars sent by this office:

CASCADE COUNTY.

Great Falls (post-office), Robbins and McFarland (October, 1891):

Average cost per acre in vicinity for preparing land for cultivation under irrigation, $7.
Average cost per acre of irrigation works, ditches, etc., $4.
Average cost per acre for annual maintenance and repairs, 25 cents.
Products: Wheat, oats, potatoes, and hay.
Average yield per acre: Wheat, 30 bushels; oats, 50 bushels; potatoes, 200 bushels; hay, 1 ton.

Great Falls (post-office), N. T. Porter (September, 1891):

Cascade Land Company: Water supply, Teton River; area under ditch, 20,000 acres.
Irrigation works: About 50 miles ditch, 16 feet wide on bottom; 1 reservoir; dam 500 feet long, 20 feet high; 3 head-gates.
Cost per mile of ditch, about $2,000.
Cost of works per acre, $10.
Cost per acre for preparation of land for cultivation (under irrigation), about $10.
Cost per acre for annual maintenance and repairs, 75 cents.
Cost of water supply to user per acre, $10 (no annual rental of water by this company).
Principal products: Hay mostly; oats, potatoes, barley, wheat.

CHOTEAU COUNTY.

Chinook (post-office), T. C. Burns (September, 1891):

Water supply: Milk River ditch: Capacity, 30,000 miner's inches; main ditch 3 miles long, 14 feet deep at upper end, 24 feet wide at bottom, 36 feet at top, gradually becoming shallower until reaching the end of 3 miles, where it is 4 feet deep, 28 feet on top, with the same width on bottom (24 feet); at this point water is divided into two branch ditches, each 16 feet wide, 3 feet deep (2 feet below surface and banks above); length 4 and 5 miles; no reservoirs or dams; 1 head gate 24 feet wide, 50 feet long, 8 feet deep, planked and covered.
Cost of main ditch, $14,000; 16-foot branches, about $550 per mile.
Average cost of preparing land for cultivation (under irrigation), $4.50 per acre (for breaking land, harrowing, and rolling).
Average cost of ditches in grain fields, from 6 to 10 cents per rod.
Cost for maintenance and repairs, small.
Cost of water supply to user per acre, 75 cents.
Area under ditch, 32 sections; under cultivation, 800 acres grain, 3,000 acres in hay; (will be much greater next year. This year is first time water was used).
Products and yield per acre: Oats, 80 bushels; wheat, 50 bushels; barley, 46 to 55 bushels; potatoes, 250 to 450 bushels; wild hay, after first year, 1 to 2 tons; garden stuff and vegetables, etc. From 2,000 to 2,500 tons of hay cut in this valley on irrigated land; no other kind cut.

[Mr. Burns irrigated the past season 550 acres; eleven of his neighbors irrigated from 800 to 900 acres of hay land. No hay was cut except from irrigated land. The seed oats used by Mr. Burns and his neighbors was grown either in Dakota, Minnesota, or Iowa, and weighs 24 to 30 pounds to the bushel. Oats raised from that seed, under irrigation, averages 39 to 42 pounds per bushel. Mr. Burns has completed two ditches 4½ and 5¾ miles long, respectively, and intends to extend the 4½-mile one across the north fork of Milk River (in a flume 120 feet long) to the valley lands, 2 by 7 miles in extent.]

DEER LODGE COUNTY.

Phillipsburg (post-office), Frank D. Brown (September 19, 1891):

Flint Creek Valley (about 30 miles long, 2 to 4 miles wide). Main water supply, Flint Creek, a tributary of Deer Lodge River.
Area under ditch, 14,000 acres.
Area under cultivation, 7,000 acres.
Irrigation works: Open ditches, each ditch owned by one ranch, generally from 1 to 4 miles, 26 by 35 feet; no reservoirs or other works.

Cost per mile of ditch, about $55 for size above indicated.

Average cost per acre for preparing land for cultivation under irrigation about $5 (includes land tilled and crops in); no preparation needed for grazing; natural grasses depended on.

Average cost per acre of irrigation works, ditches, etc., not exceeding $5.

Average cost per acre for annual maintenance and repairs, about 25 cents.

Products: Hay; also oats and wheat, used generally for fodder; yield from 1 to 2½ tons per acre.

GALLATIN COUNTY.

Bozeman (post-office), Charles A. Gregory (December, 1891):

West Gallatin Irrigation Company: Water supply, West Gallatin River (west side).

Irrigation works: Twenty-four miles canal (built over a rough and hilly country, over gulches and along sidehills, much of it in gravel and rock); first 1,300 feet is 24 feet on bottom, thence to the twenty-third mile is narrowed to 14 feet on bottom, the narrowest point at 23¼ miles from head is 14 feet on bottom, grade $\frac{6}{100}$ to 100 feet or 3 feet to a mile, except first 1,300 feet which has a fall of 2½ feet in the 1,300 feet, or over 10 feet per mile; slopes, 1 to 1, except in solid rock, which is ½ to 1; banks, 5 to 8 feet high above bottom of canal and are 25 to 45 wide at base; head gate, 24 feet wide, with 5 gates 10 by 12 and 8 by 12 (timbers); bottom of head gate 4 feet below water surface at low water; flumes, 2,722 feet, built of square timbers and 2-inch plank; flumes from 42 to 1,200 feet long, with waste gates; tunnel, 241 feet long, 5 by 12 feet, with fall $\frac{60}{100}$ to 100 feet, timbered at each end, but mostly solid rock.

Capacity of canal: Will now carry 4 feet water or 10,695 miner's inches of water.

Cost of canal, so far, $90,000; system still owns about 25,000 acres of land.

Area under ditch: The lands covered by this canal are mainly new and unbroken; there lie under it (as it may be extended by works in progress) 60,000 acres, being more than the canal has capacity to serve with water.

Area under cultivation in valley, about 50,000 acres.

Cost of water, $2 per statutory inch per year (Montana statutes).

Products: Wheat, oats, barley, timothy hay, wild hay, fruits, and vegetables.

Estimated value of products (prices paid in 1890): Average oats, $1.50 per 100 pounds; average barley, $1.15 per 100 pounds; soft wheat, 75 cents per bushel; hard wheat, 85 cents per bushel; No. 1 timothy hay, about $14 per ton; wild hay, $2 or $2.50 less than timothy (oats sometimes as high as $2 or $2.10; barley to $1.55 per 100 pounds; hay from $14 to $20).

[Mr. Gregory also mentions two other large canals in the county, the West Gallatin, 20 miles long, supply taken out of east side of West Gallatin River, capacity 8,000 inches, inexpensive head gate and wing-sieve dam, cost $60,000, built three years ago, total capacity of canal required for the land under it which is mostly all under cultivation; and the Excelsior canal, 12 miles long, cost $40,000, built by farmers and land owners under it, supplies only stockholders; carries about 8,000 inches, all supply required by lands now cultivated under it. There are innumerable farm and other small ditches—hundreds of miles of them—taken out of the many streams flowing from the mountains which surround Gallatin valley.]

MADISON COUNTY.

Virginia City (post-office); Henry Elling (September, 1891):

Average cost per acre in his vicinity for preparing land for cultivation under irrigation, from $5 to $20.

Average cost per acre of irrigation works: Ditches, etc., from $2 to $10.

Average cost per acre for annual maintenance and repairs, 50 cents to $4.

Staple products of region under irrigation: Wheat, oats, barley, potatoes, and hay.

Average yield per acre: Wheat, 30 bushels; oats, 40 bushels; hay, from 1 to 5 tons.

MEAGHER COUNTY.

White Sulphur Springs (post-office); W. H. Sutherlin (September 19, 1891):

Has 320 acres under cultivation by irrigation: Water supply, Smith River (mountain spring-fed stream); all ditches in neighborhood owned by land owners; generally open ditches, with lumber flumes where needed across deep ravines; no reservoirs.

Cost of ditches, etc., per mile, from $120 to $300 (his own ditch cost $240 per mile); cost per acre, about 40 cents.

Average cost per acre for annual maintenance and repairs, 12½ cents.
Cost of water supply to user per acre, $8.60.
Area under ditch (in Smith River Valley), 11,000 acres (above the cañon).
Products under irrigation: Wheat, oats, barley, alfalfa, timothy, blue joint, clover, potatoes, beets, turnips, cabbage, and most varieties of vegetables.
Average annual yield per acre: Wheat, 42 bushels; oats, 51 bushels; potatoes, 320 bushels.

MISSOULA COUNTY.

Cañon Ditch Company (to be completed May 1, 1892):

Ditch to be taken out "a mile above foot of Blackfoot River; contract calls for ditch 13½ feet wide on top, 6½ feet at bottom, 3½ feet deep, 7½ miles long; cost, $30,000; to irrigate all South Missoula."

PARK COUNTY.

Livingston (post-office); George J. Allen (September, 1891):

Water supply: A mountain stream carrying from 500 to 700 inches of water.
Irrigation works: 12 miles of ditch ("about 6 miles through an old channel ditch 6 feet wide, 2 feet deep"), one main headgate and one for each ranch served.
Cost of works: First cost, $200.
Cost per acre of ditches, etc.: "Near mountain stream from 10 to 25 cents, but ditch taken out of a river, $5 to $10."
Cost for annual maintenance and repairs: Twenty-five dollars per year will cover all expense under this ditch.
Area served by ditch: Nine hundred and sixty acres.
Area under cultivation: The whole 960 acres plowed and in grass.
Products in neighborhood and yield per acre: Wheat, 15 to 50 bushels; oats, 30 to 90 bushels; barley, 15 to 50 bushels; potatoes, 100 to 500 bushels; fruits and vegetables.

CENSUS FIGURES FOR STATE.

The United States Census Office (Bulletin 153) reports for this State (Mr. F. H. Newell) as follows for the enumeration year 1889-'90:

Number of counties	16
Number of irrigators	3,706
Total acreage irrigated, and in crops	350,582
Average size of each farm in acres	95

NEW MEXICO.

Quoting the words of the monograph on New Mexico, which forms part of a report by the United States Signal Service, on "climatology, irrigation, and water storage in the arid region," it is to be said that the logical sequence of such inquiry can be summed up, as showing that—"Agriculture depends on irrigation, irrigation depends on the rivers, the rivers depend on the clouds whose attenuated humidity is made to appear as rain and snow by the influences largely controlled by the altitude and configuration of the mountains." The determining causes then, are to be found "in geographical physics." The mountains both supply and direct the rivers. In New Mexico the Rockies lose their continental individuality, and southward from Pikes Peak, but chiefly within the land of "Poco Tiempo," this great range becomes a series of semi-detached masses and sinks into rolling formations, spreading out as sloping mesa or table-land, though still of high altitude. Below Marshall Pass in Colorado, the Continental range divides—one portion entering New Mexico to the southeast, the other swings to the southwest. This portion forms a watershed between the Rio Grande and the Rio San Juan, making an important part of the basin and plateau hydrography of the Rio Colorado system. Between these divisions of the Continental range is the superb basin valley or dessicated lake bed known as the San Luis Park. From the western portion thereof rises the Rio Grande Bravo del Norte and through which it flows, making almost a direct course east and west by a little north and south, until it turns directly southward, forcing its way through the Raton range, a part of eastern limb of the Rockies. This section preserves more fully the characteristics of the great range and it is locally known as the Sangre del Cristo, Taos, Raton, and Santa Fe ranges. The Raton, which is the extreme eastern section, forms a plateau or table-land with a general elevation from 7,000 to 4,000 feet. At the latter altitude it descends 1,000 feet or more and almost precipitously into the valley of the Upper Pecos, which flows through and divides the eastern portion of New Mexico. As a water storer the Raton range, fed also from the higher altitudes of Taos and Sangre del Cristo, is destined to play an important part in the reclamation of an area of great extent, fine climate, fine possibilities for agriculture, and of striking topography and picturesqueness. The Rio Grande Basin, below the San Luis Valley, is dominated on its east side by the Taos and Santa Fe ranges, rapidly breaking away into the detached elevations and mesa known as the Oscuro, Sierra San Andreas, Organ, and Sacramento mountains. On the western side the formations take the name of Datil, San Francisco, and Mogollon ranges, till reaching and passing the Upper Gila they fade away into the Sierra Madres in Old Mexico, forming the Chiricahua Mountains in southeast Arizona.

New Mexico, as a whole, can be regarded as a broken plain of 5,000 feet elevation, controlled by two systems of higher altitude, marked by several smaller ranges on its eastern and southern faces, with one large

Rio Pecos near Roswell, New Mexico.

bisecting river channel cut through its center from north to south, and having another marking in a similar manner about two thirds of its eastern half. The result of this mountain topography is to divide the region as by walls, separating it into different areas or chambers, each having different relations to hydrology and climate. Three-fourths of New Mexico then has an average elevation of 5,000 feet. In the southern portion it is less, generally 4,000 feet, and at three points in the Rio Grande up to Fort Thorn, along the Canadian to Fort Bascom, and the Pecos Valley up to Roswell and above, the altitude runs down to 3,000, and in the last named area to about 2,000 feet above sea level. Two range systems rise from the general level to the height of over 7,000 feet each. They are grouped, says Lieut. Glassford, "like a wall against the western boundary or form a dependent projection on the northern line, thus accentuating the southeastern facing of the system. From this general mountain altitude many summits rise 2,000 feet or more and there are peaks which lift their precipitous slopes and bald, deeply scored faces, to an altitude of from 10,000 to 12,000 feet. Their climatic purpose is to extract moisture from the atmosphere for the benefit of the lower levels; they do more than this, for the rain carries away the disintegrating rock to enrich the plateau and the valley beneath." So far then as climatic influences are concerned, these topographic statements show that "for the rest the country is mesa of even surface despite its great elevation; it is nearly level table-land, whose depressions and elevations are but slight, presenting to the lower plateau a characteristically bluff face. Such a surface, looking to leeward, can oppose but little resistance to the moisture-bearing wind as it passes over it; it must pass the wind and its freight along to condense upon the mountains. Arizona faces the prevailing humid wind and opposes to it a flight of steps; New Mexico is almost entirely on the leeward side of the mountain ranges and exposes a minimum of bluff surface to the wind. Hence arise different climatic conditions, and their study is thus," says Mr. Glassford, "intermingled with the correlation of the mountain systems."

The several drainage basins are marked by the great divides which characterize the peculiar parietal formations of New Mexico. The Continental Range is first and forms the southwest watershed between the two oceans. It enters the Territory in Rio Arriba County and passes into Mexico along the Sierra de las Animas. It contains two large basins, the San Juan and the Gila, and the small one made by the Zuñi drainage. There are ten peaks within its borders, ranging in elevation from the Animas, at 6,105 feet, to the Jamez, at 11,260 feet. The second divide approaches the meridian at middle of the territory. Its northern ridge is found along the Sangre del Cristo Range, until it finally sinks in the high mesa below Santa Fé. It then forms a high plateau across the Gallinas to the Sierra Blanca, and disappears in Texas by way of the Sacramento Range. It contains eight outlying peaks, ranging in altitude from the Franklin, at 6,890, to the Tucha, at 13,150 feet. The western shed may be related as the Pacific and the eastern as the Atlantic divide. Geologically speaking, there are within the area, four distinctly marked epochs. They are the Archean, entering from Colorado; then follows the palæozoic and mesozoic periods. The cretaceous covers most of the lower surface and outlying areas. "There occurred four distinctly marked upheavals of eruptive rock at wide intervals. As conditioned by these general characteristics the rivers of the Territory are few." The river systems of New Mexico, then, are the San Juan to the northwest, the Gila to the southwest; the Rio Grande through the central basin from north to south, the Canadian in the north from northwest to southeast, and the Pecos from north to south in the section lying east of the mountain ranges that easterly border the Rio Grande. In this division there is to the east a subdiversion, marked about the latitude of Las Vegas. East and north of this line "the waters drain through the Canadian, the Cimarron, and the Arkansas into the Mississippi; south of the line the Pecos drains the rainfall across western Texas into the Rio Grande." Two very important systems of irrigation are found within these drainage basins. In Colfax County to the north, supplied by the headwaters of the Canadian, the owners of the Maxwell grant, with other landholders, are carrying forward an extensive system of open storage and distributing works, by which about 75,000 acres of table-land are being brought "under ditch" and some 6,000 acres of which are already under cultivation.

Besides these enterprises in the mountain table-land and under the waters of the Canadian there are a number of local irrigations in progress for orchards and farms in Colfax and Mora counties. Some of these are of value to the student as illustrating the altitudes at which fine fruit may be successfully grown and good grain and forage fields be sown and harvested. Mr. S. W. Dorsey, one of the largest land-owners and ranchmen whose home residence, Chino Springs, Colfax County, with an altitude of over 8,000 feet, has its fruit trees, berries, and vegetable garden supplied by water through a half-inch pipe from a little but constant phreatic flow obtained by an opening made in the side of a bluff at the back of the dwelling and out-buildings, is engaged in constructing reservoirs on the table-land for the purpose of storing local rainfall and storm waters. In the counties of Lincoln, Chaves, and Eddy (also San Miguel), formed out of the Pecos basins, there are two extensive systems of water storage, distribution, and cultivation by means of irrigation now in progress. One of these, in Eddy and Chaves counties, has irrigation works constructed to irrigate nearly 300,000 acres. Artesian waters have also been obtained at Roswell, and large promises of an important supply are found in several directions. The southwest basin or the Upper Gila is small and not more than 50 miles in width. Like that of the San Juan Basin in the northwest, it belongs climatologically to the Pacific group. There is a growing activity in the San Juan Basin. From there directly southward the areas of possible reclamation or present cultivation are small. There will be an increase in this direction of small areas at favorable points as farmers and settlers comprehend more clearly the conditions under which a drainage supply may be tapped, dug out, bored for, and recovered for use in cultivation. In the Upper Gila Basin the rainfall is commonly sufficient to make a success of the ranchers' rude but profitable "dry" farming.

> This drainage basin is therefore removed from the discussion of irrigation as influenced by climate, but its bounding ranges remain as one of the important and far-reaching factors of the climatic problem of the Territory. (P. 320, Signal Service Report.)

The central basin, that of the Rio Grande, forms not only the principal pathway north and south, but it is also the chief seat of population at present. Its waters are mainly from the snows of the Continental Divide within the borders of Colorado, though replenished by the local precipitation of its subsidiary basins. The tributaries are numerous in its upper course, but after leaving the Taos Cañon they become less frequent; in fact it has, below the point at which the Santa Fé and Galisteo pour in their torrential flow, no confluents of any magnitude. The oldest irrigations within the United States are to be found within this valley, unless exception be made of the phreatic cultivation, whose evidences are to be traced in connection with the ruined Pueblo towns of the Rio Chella, etc., and in the Salt River Valley, Arizona. The 18 Indian pueblos now existing in New Mexico are sustained as to cultivation by the Rio Grande's hydrological conditions, and they long antedate the present Mexican farmers. The oldest of the latter settlements is undoubtedly that in the Mesilla Valley, the rich soil of which has been in constant cultivation under irrigation by them the past three centuries. Portions of the Santa Fé Valley above settlements at Albuquerque and in San Bernalillo counties are next in order, and later still are the farming communities of Conejos and Costilla counties in Colorado.

The hyetophysics of New Mexico will be more readily comprehended after this summary of its topographic conditions. Lieut. Glassford says:

> The Pacific Ocean is the reservoir of Arizona. Its evaporated waters are carried by the prevalent southwest winds over plateau systems which gradually increase in altitude and every such step opposes its maximum condensing surface to the characteristic wind. The culmination is reached in the system of lofty ranges which overtop the highest plateau. From this local action of condensation differentiating the circulatory inspiration of continental lows which move east of the Rocky Mountains there arise two systems of precipitation which present a noteworthy difference in character. The winter rains are diffuse as regards the area of territory affected; they are moderate in force; they are interrupted by the anticyclonic types of high barometer and cloudless skies, which are distinctive of the Pacific coast weather; they are in unmistakable correlation with the systematic climate of the country. The summer rains are different; in extent they are concentrated; they are uniformly local and attributable to local influences; they are characteristically of great violence, which often seems to justify the mistaken appellation of cloud-bursts. One other point needs to be held in mind, and that is that the records show in reality only the minimum fall of rain, since observers' stations are mainly in the valleys where their gauges make no record of heavy rains which are in sight upon the surrounding mountains.
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> That the rainfall of New Mexico is but a continuation of the Arizona system, a projection of Pacific humidity across a congeries of condensing mountain bodies the ratio of whose efficiency is geometrical, will appear from a study of the phenomena here presented. For convenience in support of this proposition the records of rainfall will be presented under the two titles of winter and summer rains, which the period of their occurrence most naturally suggests, a distinction which, provisionally assumed for convenience, will be found clearly proved step by step as the argument proceeds. (Irrigation and Water Supply in the Arid Regions, p. 321.)

The winter rains in New Mexico are to a considerable extent of the Pacific type, though they are to more or less extent obscured by their long inland movement. Their tendency is to diffusion; hence a certain loss. The climatic conditions of the Rocky Mountains affect them seriously, especially as to "the march of extensive areas of low barometer," which are deflected to the north by the impact of the range, and thereby cause their movement toward the Atlantic. They differ also from the Arizona season in being divided "by longer and shorter periods of high barometer." The winter precipitation is expected by December in Arizona. In New Mexico it does not begin as a rule till the earlier days of January. The basins directly under Pacific influences are in line with the isohyetal or rain curves of Arizona. In January the general average of the Territory conforms to the law already indicated, and in February, when these seasonal curves begin to break "down into scattered local areas," the conditions have become markedly strong in New Mexico. By April the winter rains are definitely ended. But in the eastern or Atlantic divide section, an area of considerable precipitation remains. This follows the high summits of the Sangre del Cristo until it sinks into the table-land or mesa of 4,000 feet, thence it tends southeasterly across the Pecos head-waters region as far as Gallinas Spring, whence it sharply curves to the north and extends over the Raton Range. The winter rains in the nomenclature of the meteorologist are marked by isohyetal curves of from 7 inches to 1 inch of precipitation. These curves are outside the mountain lines. The 5-inch curve is associated with the Arizona rains, and, with that of 4 inch, belongs to the Gila Basin and the head waters of the Colorado Chiquito. A curve as high as 17 inches appears on the mountains of this area. The 6 and 7 inch curves are found about the high levels of the Sierra Blanca, and the 5-inch curve related to them runs northward along the westward wall of the Pecos Valley as far as Colorado, just west of the upper Canadian. A curve of 2 inches is drawn across the plains of the Mimbres as far east as the Mesilla Valley, and thence it deflects southeasterly into the Pecos. The 3-inch follows the Mimbres lines until it reaches the Rio Grande Valley. It is then drawn sharply northwards to Socorro, where it expands to include Laguna and Albuquerque, whence it again deflects southwards until it reaches the Organ Mountains. These curves indicate the diffusive and diverting influence of the topography on the aqueous currents borne to New Mexico from the South Pacific Ocean across Arizona.

The summer rains are otherwise influenced, for the highest or 11-inch curve appears upon the levels west of the Canadian River and on the cañon course of the Pecos. In some parts of its progress the curve reaches the 15 inch, which includes Las Vegas and Fort Union. Two segments south of these points draw close together at Luna and then expand further to the south, reaching the 14-inch curve at Fort Stanton. The lower summer curves are found in the sections most favorably affected by the winter rains. The minimum curve of 4 inches is found in the southwest. An adjacent one of 5 to 6 inch crosses the Gila Valley, skirting the Mimbres plains (Deming and northward) and passes out into the lower Rio Grande Valley. There are high curves of from 8 to 15 inches along the Continental Divide summits. The seasonal precipitation drawn in from Arizona along the San Francisco Valley gains a systematic curve of 7 inches, running over the mountains until it reaches the Rio Grande at Fort Seldon, and thereby favorably affects the Mesilla Valley. It is then drawn northward along the western wall as far as Embuda, and thence deflects southward, finally passing into Texas.

These statements illustrate the radical distinction in type of the winter and summer rains. The author of the New Mexico monograph utilized here says: In winter that humid winds are drawn "across the region under discussion by the influence of low areas over regions near or remote. In the summer the winds rush from all sides towards the heated mountain masses, and the precipitation resulting therefrom is distinctly local" (p. 324). In winter, what are termed "the continental lows" hang long upon the Rockies or are swept eastward "with varying velocity." This type "is a simple one and well characteristic climatic group." It is thus described:

> Step by step the humid winds are drawn over graduated plateaus and extrusive summits, and at each higher step discharge so much of their moisture as is a surplusage over the saturation amount of atmosphere of a given tenuity at a given temperature. There is nothing violent in these systematic drafts of humid air from the sea toward the continental cyclones; the air is chilled by the seasonal causes which make the winter climate; the earth surfaces soon become largely covered with snow and their radiating influence is thus mechanically obliterated; the air lies in practically

even strata of uniform temperature. The humid wind is drawn along these ruling conditions; on every plateau it discharges down to the point of saturation; the diminution in absolute amount of moisture is constant and large; by the time it overlies the Rio Grande trough its last available moisture has been condensed by the heights of the Continental Divide and sifts down to the leeward. Practically desiccated the current reaches the summits of the eastern or Atlantic divide; it has but little rain to deposit for the immediate agricultural benefit of the plains; such precipitation as is induced appears as snow which forms a storage reservoir whose supply is constantly utilized until July. Therefore are the winter rains confined in the main to the western member (p. 324).

The summer winds or "temporales" are from atmospheric strata, drawn from the sea over land surfaces, under the influences "of mechanically directing guide planes," at sea level and mean temperature "calm air is in a position to take up and hold in suspension moisture up to the point of saturation." As a result of change of higher position and of temperature, the point of saturation is also changed; there is more moisture than the aërial gases can hold and precipitation follows. Another factor is that of radiation. If topographical surfaces are heated by the suns rays, the aqueous currents as they rise and pass are immediately affected. This factor is the dominant one in relation to the "temporales." Lieut. Glassford says:

> When the elevating plane over which the air is drawn is covered with snow, this factor is in its lowest terms. Snow reflects the incident solar heat back to the air through which it has just been transmitted, and as the air is highly diathermanous it is very little affected by this original and reflex passage of heat, which furthermore is near its minimum during the season when precipitation takes the form of snow. Though an excellent reflector of heat, snow is also a notably poor radiator, and forms a screen which prevents in a large measure the diffusion of the heat which the mountain mass has collected by absorption and stored during a warmer season. It therefore appears that the temperature of the surface of a snow-clad surface of elevation differs but little from the absolute temperature of air normal at the same elevation. Over a region governed by such an elevation it is most likely that the superterranean planes of temperature and saturation are evenly distributed. In such case the induced air body raised by the guide plane of the mountain slope into successive planes will move continuously and with the least disturbance, and will lose of its humidity only such a minimum amount as will suffice to reduce it to the saturation point of each successive plane, and thus will carry its maximum to be precipitated on distant regions in its appointed course.
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> With the vanishing of this screen of snow the conditions proportionally alter. The surface of elevation, with its soil and rock masses, ceases to reflect the incident heat ray of the sun, but absorbs much of it. At the same time it radiates the heat which it receives, currents are formed in the surrounding air, and the mountain becomes a focus of activity, about which are currents rushing rapidly skyward and a lateral indraft to supply the place of the air withdrawn by this action of convection. The air passing the snow-clad mountain is raised to the minimum elevation which will enable it to pass beyond; its precipitation is the minimum, its reserve is available for higher ranges. The air, influenced by the radiating mountain mass, is forced to the highest elevation which the upward current can reach, as is shown by its frequent precipitation as hail; it is subjected to the greatest change of pressure and temperature; its excess moisture and consequent precipitation reaches the maximum; it is almost desiccated, and on even higher ranges beyond can cause no precipitation. All these theoretical features are observed in the New Mexican rains (pp. 24, 25).

From June to September the effects of this phenomenon may be seen practically illustrated. In June the ranges are still snow clad, though vanishing. There is the minimum of discharge as a result, with vague diffusion over large areas. In July the snow is swiftly disappearing, and humidity is restored to the air, while the rain becomes general to the leeward of the mountain. There is but little difference in precipitation for August. In the western field the humidity is passed "rapidly to very high altitudes and makes a high precipitation upon the immediate region." In other words, in that portion which belongs to the Pacific climatic influences, the summer rains are adaptable for storage use, and not for immediate terrane distribution. The eastern section, or Atlantic divide, on the other hand becomes a focal ridge of "great radiation and intense activity of convection." The largest precipitation then is in the two months of July and August. In September the "temporales" disappear, for the

> two mountain masses are fully developed as ridges of radiation and convection, the available humidity has been almost exhausted, and although the condensation takes place at high altitudes yet the general air temperature is so much elevated that the practical effect of height on temperature is considerably lessened. The rainfall is materially less; it appears as indefinite areas of slight intensity, and thus the temporales disappear (p. 326).

Evaporation observations, Mr. Glassford says, authorizes the drawing of provisional curves over portions of New Mexico, of from 70 to 90 inches of annual loss. The lowest curve corresponds with the Sangre de Cristo and Pecos-Canadian section; that is the north end portion. The 80-inch curve sweeps in across the southeast portion, where it sharply recurves and goes westward to the Gila Basin. The highest curve affects the whole of the southern section of the Territory. According to the weather-service paper, New Mexico formations are directly related to phreatic supplies. The writer quoted accepts the term "underflow" first used by Mr. J. W. Gregory, of Kansas, and since brought into special use by this office during the "Artesian and Underflow Investigation" as the one best adapted to express the nature of the subterrane or drainage water supplies which were reasonably conjectured as existing when our inquiries began, and for the use of which ample proof has already been obtained. With Mr. Glassford this office agrees that it—

> Must be rigidly stated and strictly understood that in the present state of knowledge no competent evidence exists to prove that this underground water supply partakes in any sort of the nature of a stream sufficiently to authorize the use of the word flow. In individual instances a flow may be proved in continuation of the aboveground flow of the lost rivers characteristic of the region, but that the general body of underground water has any such progression is certainly not proven.

No general claim for sub-flow has ever been made. Only in assured cases, subject to demonstration, would it be allowable. But that all phreatic waters have a propulsive or directive movement, however slow, is in my judgment a demonstrated fact. The evidence is ample and extends over many years and different lands. The existence then of phreatic waters in New Mexico is already established. In the annual report on Internal Commerce, for 1888, published for the Bureau of Statistics, U. S. Treasury, there is among others a valuable paper on this Territory giving by towns and villages the location and character of earth waters utilized as springs, wells, etc., for town and farm purposes. The number is surprisingly large. Artesian water has already been reached a few miles below Springer, where the Raton tableland begins to decend into the upper Pecos wall, and at Roswell, in the lower Pecos Valley, where a number of flowing wells are now in operation. At Eddy two wells are being drilled with good prospects of success. This is a region of heavy springs, and to the eastward of the Pecos rising water is obtainable in all directions and at moderate depths by dug wells. At Deming and the neighborhood nearly 100 such wells are in operation. The lifting power employed is that of the windmill. On the Journado del Muerto several tubular wells are a moderate success. South of Galisteo Creek, on the Florida plains, and in Manzano Valley, as well as in the Pecos Velley, such waters have been found. The extensive intra-mountain plain or valley, lying to the east of the Organs and between that range and the Guadalupe, is without a single surface stream or spring. Yet there is little doubt that it is extensively supplied with underflow or phreatic waters, and there is reason to believe, as the existence of old ruins in the upper portion shows, that it must once have been watered by flowing streams, having large portions subjected to irrigation by the same prehistoric race that have left their industrial evidences elsewhere in the southwest. As these underflow waters are obtained, the question of power becomes one of importance. Mr. Glassford recommends the utilization of the wind by means of mills and gives the following table (page 327):

Hourly wind movement.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Santa Fe	7.1	7.2	6.9	8.0	7.6	6.5	6.0	5.4	5.1	5.9	6.2	5.8
El Paso	4.9	5.6	5.8	6.6	6.3	5.7	4.7	4.8	4.5	4.3	4.5	4.8

IRRIGATION COMPANIES.

According to the latest report of the governor, the following have been incorporated since September 1, 1890:

The Pope Land and Irrigation Company. Locality: East side of Pecos River, in Eddy County and Texas.
Apache Valley Irrigation Company. Locality: Apache Valley, Colfax County.
The San Mateo Irrigation Company. Locality: San Mateo River.
The Rio Grande Land and Irrigation Company. Locality: East side of Rio Grande, in Sierra and Donna Ana counties.
The Sacramento Irrigation Company. Locality: Sacramento River.
Mimbres and Deming Ditch and Pipe Line Company. Locality: Mimbres River, Grant County.
The Puerto de Luna Ditch and Colonization Company. Locality: Pecos River, San Miguel County.
Bosque Redondo Irrigation Company. Locality: Pecos River, San Miguel and Chaves counties.
Rio Grande Interstate Land and Improvement Company. Locality: East side Rio Grande, from 200 yards below Earlham Bridge to south boundary of Refugio Grant, about 18 miles.
The Felix Land and Water Company. Locality: Rio Felix, Lincoln and Chaves counties.
The Mimbres and Deming Canal Company. Locality: Mimbres River, Grant County.
The Tijeras Water Company. Locality: Tijaers Cañon, Bernalillo County.
The La Plata Ditch Company. Locality: La Plata River, San Juan County.
The Santa Fe Irrigation Company. Locality: South side Rio Santa Fe, Santa Fe County.

IRRIGATION PROGRESS.

The future of the Territory of New Mexico largely depends upon the increase of its cultivated area through irrigation. The great systems now in process of construction and enlargement on the Pecos, Nimbres, and the Maxwell grant, illustrate the rapidity with which the art is progressing. These systems are elsewhere described.

In San Juan County, according to Mr. J. G. Kello, there are approximately 200 miles of main ditches, covering about 24,000 acres of land. About 175 miles of these are owned and operated by the farmers themselves, and are partnership ditches and not incorporated. This length of ditches is all under operation. There are also from 40 to 50 miles of uncompleted ditches. It is estimated that it requires at least one cubic second foot to irrigate 160 acres of land in San Juan County. The average cost of water throughout this county is abont 75 cents per acre.

In Santa Fé County during the past year, 1891, irrigation activity has been very marked, and as a result 600,000 pounds of apples and

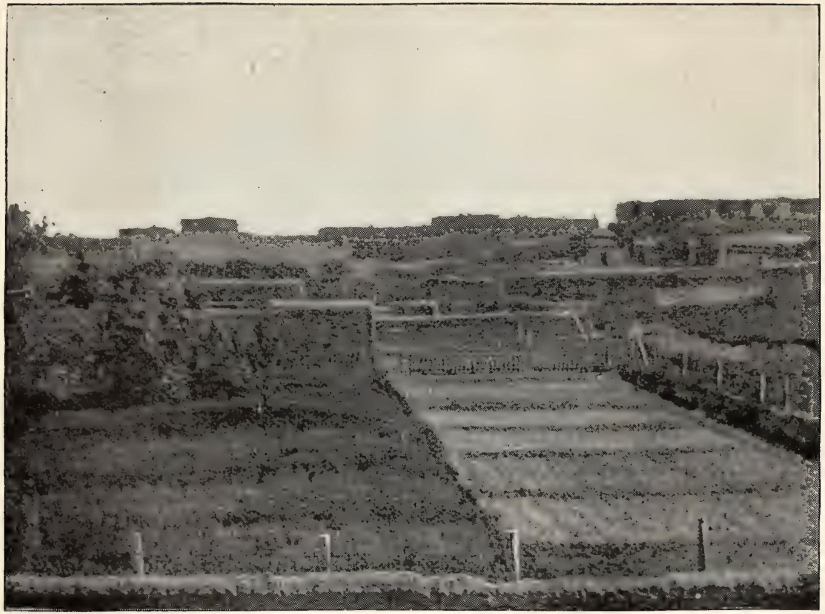
300,000 pounds of other fruits, raised by irrigation, were shipped from Santa Fé.

Mr. Arthur Boyle, one of the best horticulturists in that locality, furnished the following information: His orchard of 6 acres was planted in 1886, and bore its first full crop in 1888. Apples, peaches, and nectarines flourished; raspberries, with the exception of the cuspid, stand the winter cold without protection; other berries mature earlier than in the neighboring States and Territories, and enjoy a noncompetitive market for about three weeks. Land, with water, fit for fruit near Santa Fé is worth $100 to $150 per acre. The same land well planted will command $1,500 per acre and upward. In 1888 Mr. Boyle made an experimental shipment of peaches from Santa Fé to a merchant in Denver, with whom he was unacquainted, and received a telegraphic order for all he could send. This was because the fruit was not only of a high grade but was on the market three weeks before the California crop. Last year he sold $2,700 worth of fruit from his 6 acres.

The style of irrigation is the old Mexican acequia, and there are about 700 users of water in Santa Fé. Under the law no man can vote for mayor domo acequia unless he is an actual irrigator. The poll books of precincts Nos. 3 and 4 show that over 300 persons voted at the last election in 1890. In the following precincts the people depend entirely upon irrigation for a livelihood: Santa Cruz, Espanola, Chimayo, Nambe, Pojoaque, San Ildefonso, Tesuque, Upper and Lower Santa Fé, Agua Fria, Bajada, and Galiesteo. These will average 55 votes in each precinct, or about 660 irrigators. There are 17 irrigation precincts in Santa Fé, and nine-tenths of the irrigation is carried on by the native resident New Mexicans.

Wheat yields 30 to 40 bushels to the acre, at a general average of 75 cents per bushel. The cost of production would be about 15 per cent of the gross value. Alfalfa averages 2½ tons to the acre, and for the last three years has sold for $95 per acre, gross. It costs about 10 per cent to cultivate. Fruit will yield an average of profit of $250 to $1,500 per acre. As high as $800 worth of apples alone have been sold from 1 acre near Santa Fe.

The number of acres under cultivation in Santa Fé County is not large, owing to the scarcity of water and rainfall. The possibilities of redeeming large tracts by the construction of reservoirs and ditches are, however, shown to be great, as reported to this office by Mr. Hartman, C. E. The sections now under cultivation by irrigation are in the Rio Grande Valley or along the bottoms of creeks; but as the latter sink on reaching the lowlands, or as soon as they reach the cretaceous formations, an immense amount of water is allowed to run to waste during the spring by the absence of suitable provisions for its storage. The soil is excellent, and produces large crops of the best quality when irrigated. Valleys and cañons in the mountains or close to their base have a heavy silt. All of the streams in the county emanate from the Santa Fé range, flowing westward into the Rio Grande. These water courses, from north to south, are the Canada Chimayo, Nambe, Tesugue, Santa Fé Creek, heading at Baldy and Lake Peaks, respectively, and Galisteo Creek, rising with its two heads, Apache and Canoncito creeks, near the summit of the southern end of the Santa Fé range. Their waters are derived from snow, rain, and springs of the mountains, in Archæn rocks, flowing hence through carboniferous beds, finally reaching the cretaceous formations (Santa Fé marls) which fill the valley between the mountain range and the Rio Grande, superlaid nearer the latter by sheets of basalt thrown out from the Tetilla.



Irrigated Market Garden in Santa Fe, New Mexico.

Santa Fé County has an area of about 2,159 square miles, or 1,381,760 acres, of which 603,040 acres are covered by Mexican grants. Of these about $\frac{6}{50}$ per cent are strictly agricultural, *i. e.*, irrigated, used without irrigation, or are easily put under ditch. They may be classified as follows:

	Acres.	Irrigated.	Irrigable.
1. In Rio Grande Valley	13,120	4,500	8,620
2. In Chimayo Valley	1,280	640	640
3. In Nambe Creek Valley	2,880	800	2,080
4. In Tesuque Creek Valley	3,520	1,520	2,000
5. In Santa Fé Creek Valley:			
(*a*) From waterworks reservoir to Aqua Fria, 8 miles	8,320	5,760	2,560
(*b*) Ceeneza and Ceeneguilla	2,560	960	1,600
(*c*) Vicinity of Penos Ranch	320	120	200
6. In Galisteo Creek Valley:			
(*a*) In Apache Creek Valley	1,420	140	1,280
(*b*) In Canoncito Creek Valley	480	180	300
(*c*) On Long Grant Valley	2,400	200	2,200
(*d*) At Casa, Colo	1,920	920	1,000
(*e*) In Galisteo Creek Valley to Cerrillas	3,360	400	2,960
(*f*) In San Cristoval Arroyo Valley	2,080	800	1,280
(*g*) In El Chorra Valley	1,920	160	1,760
(*h*) In San Marcus Arroyo Valley	1,120	160	960
7. In Cañados Facundo, Ortiz, and Galleyos	1,380	680	700
Total	48,080	17,940	30,140

The 17,940 acres now under cultivation and irrigation have their water conducted to them by a system of ditches (acequias madre) and their laterals, with a length of not more than 33 miles. The general formation of the country is very favorable in its natural slopes.

The area of land which may be cultivated for the raising of crops without irrigation is 18,540 acres.

These lands are situated on the Pecos Mesa, in the vicinity of Glorieta, on the upper portions of Arroyo San Marcos, and the various openings from the mountain sides into the plains on the east and west.

Bottom lands can be made available by the construction of dam storage for reservoirs to the extent of 12,354 acres. They are on the Santa Fé Plains.

	Acres.
1. Valley of the Arroyo de los Chamisos	2,880
2. Valley of the Arroyo Hondo	3,560
3. Valley of Cañada de los Ranchos	1,600
4. Valley of Cañada de los Minos	934
5. Valley of Cañada Aocha	1,660
6. Valley of Arroyo San Marcos	1,720
Total	12,354

This is upland available by the construction of small dams to the extent of 20,840 acres. There may be located (1) on the Santa Fé Plains, surrounding an abandoned artesian well location, 5,200 acres; (2) in basin worn out by the Arroyo San Cristobal and Arroyo La Iara, south of Galisteo, 5,640; total, 10,840 acres.

Santa Fé Creek runs about 3,326,000 cubic feet of water every twenty-four hours during February, March, and April of each year, giving a sufficient quantity to irrigate 80 acres per day, or 8,000 acres in, say, one hundred days. This amount now runs to waste. The quantity of water during May and June is somewhat less, but generally sufficient to irrigate the land now under cultivation. The water of the rainy season, July and August, is also used for the same purpose. All the water of the remaining five months, September to February, which is calculated to amount to about 250,000,000 cubic feet, would, if stored, be sufficient to irrigate about 6,000 acres more; or, in other words, there is sufficient water in Santa Fé Creek to irrigate 20,000 acres if properly handled.

Nambe Creek runs about three-quarters of the quantity of Santa Fé Creek. Tesuque Creek, after the junction of its several heads, about the same as Santa Fé Creek. Galisteo Creek about one-half of Santa Fé Creek to within 2½ miles of Lamy. Arroyo of San Cristobal runs about one-third of Santa Fé Creek.

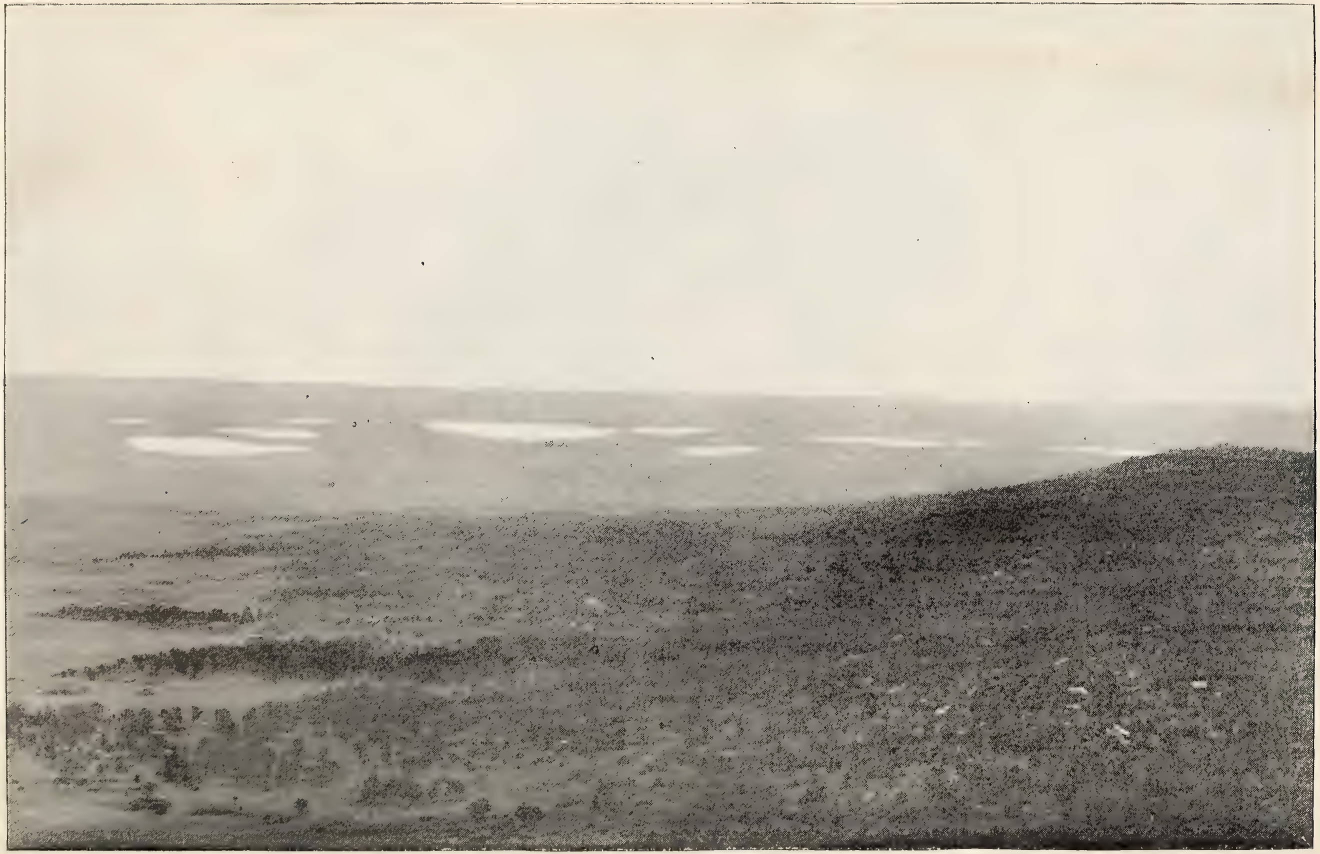
Nambe, Tesuque, and Santa Fé Creek carry their water as long as they run through archæan and carboniferous formations, and the heads of Galisteo (Apache and Canoncito Creeks) while passing over the Archæan, which is superlaid directly, at its base, by Dakota formations. All become intermittent on reaching the Cretaceous or Galisteo beds, respectively. By building dams across the creek beds at intervals of several miles all the water could be retained and made use of to irrigate large tracts of lands now lying idle. The heads of arroyos and cañadas, on the Santa Fé Plains, afford opportunities for building reservoirs. In the southwestern part of the country, where the cañadas open eastward from the mountain slopes on the west, dams for reservoirs are easily constructed. Water can be obtained in the apparently dry creek bed of the Galisteo at a depth from 15 to 20 feet.

IRRIGATION ON THE RATON TABLE-LANDS.

The table-lands of the Raton Range have several times been referred to. That portion under what is known in New Mexico as the Maxwell grant is the seat of an irrigation enterprise of a most important character. The altitude, topography, hydrography, and climatic conditions all unite in giving prominence, from both an engineering and economic standpoint, to the irrigation works, administration, and cultivation that are in progress in northeastern New Mexico. The special agent made a close personal examination of the area and hydraulic system in the early summer of 1891. Impressed with the belief that the success of the systems in operation upon the Maxwell grant would demonstrate the possibility of an arable reclamation of many million acres of high table and plateau lands, several days were given to the inquiry and over 100 miles of driving was done at an elevation between 6,400 and 8,000 feet. The conclusions reached are given in a condensed statement of the notes made at the time. There are two ditch systems under the Maxwell operations and one other under the control of Mr. Springer. The source of supply is found in the snow-fed head waters of the Canadian and Cimarron rivers and in the local precipitation of the foothills and table-lands.

The Springer Ditch (Maxwell) system contains about 22,000 acres under ditch. There is one large reservoir called Springer Lake, situated at 5 miles from Springer, with a capacity of 5,000 acre-feet of water; besides there are also several smaller lakes and one settling basin. The smaller lakes together have a storage capacity of, between them, 1,000 and 1,200 acre-feet of water. There are 55 miles of main ditches and large distributories or laterals. The water for this system is obtained from the Cimarron and Ponil rivers, and the head gate is situated at the junction of these rivers. It is not yet possible to estimate with accuracy the average flow per year of these streams, for the first gauging station was only established on the Cimarron in 1890.

The grade of the main ditch is about 5¼ feet per mile. It is 20 feet



Raton Table Land Reservoirs.

View from Saltpeter Rock, Taos Range, Colfax County, New Mexico.

wide at the bottom and about 4 feet deep. There is no question of the water supply made being equal to all wants. If all the land were sold under the Springer system, any demand for water would have been satisfied. As to the Vermejo system, there can be irrigated at present 30,000 acres, and that, too, without further extension of the system by building additional reservoirs. The reservoirs and their capacity are as follows:

	Acre-feet.
Lake 1	200
Lake 2 (Laguna Madre)	2,100
Lake 4	300
Lake 5	1,000
Lake 7 and 8	11,000
Lake 10	200
Lake 12 (Oyster Lake)	3,000
Lake 13	1,700
Lake 15	200
Lake 16	200
Lake 20	300
Total	20,200

Besides these there are several depressions, which can be utilized by making deeper cuts and building embankments around them, if at any time the system should be increased. There are about 50 miles of main canals and main laterals of same depth and width as those of the Springer system. The Vermejo system may be extended to the north and east. Below the present head gate, about 4 miles lower down the river, an additional ditch is being built, which, tapping the Vermejo River, will receive an additional flow on account of several springs rising thereabouts, between the present head gate and the ditch now building. This is called the low-line ditch, and will cover an additional area of 7,000 acres, at a total expense of $7,000, including a rather expensive iron flume, a late invention of a Denver patentee. It is proposed, in the event of conditions warranting it, to make an addition to the system by going higher up into the cañon, with a view to the possibility of dry seasons. To increase the amount of water, it is proposed to build a storage reservoir about 15 miles above the Vermejo head gate in the mountainous part of the river; the plans are already made, the location chosen and surveyed. Owing to the amount of water now available, this project is postponed to another year. Such storage reservoir would be located at the junction of the Caliente and Vermejo rivers and would have a capacity of 5,000 acre feet; the expense of this construction may be estimated at $50,000; and the reservoir could be filled repeatedly during flood seasons every year.

It is also designed to construct a reservoir covering 3,500 acres to collect the waters from the Cieniguilla and Cimarron rivers at the head of Cimarron cañon, about 30 miles northwest of the present head gate of the Springer system. This reservoir, which has been surveyed, would irrigate 160,000 acres; the proposed dam would be 140 feet high, 100 feet long on the bottom, and 275 feet on top. It will contain 312,000 cubic yards of material. It would irrigate a great deal of land which can not at present be covered by either the Vermejo or Springer system. Besides this, there are other projects surveyed: First, to collect the flood waters of the Van Bremmer, Serososo, and Ponil rivers into a series of natural lakes, each of which will hold a large quantity of water, with a dam to be built around them; second, a project to collect the waters gathered through the heavy floods which every year occur in Crow Creek Cañon. This, however, would be rather expensive and would not cover more than 3,000 acres. A third plan is to collect the waters that come down Raton Arroyo and the Chica Rica Creek and its various branches, and from the melting snows which come down from the Bartlett and Chica River mesas. This proposed system is located east and southeast of Raton, near the eastern boundary of the Maxwell land grant, and would cover 12,000 acres, which are located partly on Government land outside of the Maxwell grant.

The waters of the grant belong to the hydrographic basin of the Canadian River, that is, to its head waters; the Cimarron is only a branch of the Canadian. As to altitude, the proposed storage basin on the Vermejo River would be located at about 7,200 feet, and that at the head of the Cimarron at 8,100 feet. The area of irrigable table-land on and between the two existing ditch systems is about 75,000 acres in extent. The whole area which could be embraced in the different schemes for irrigation, now built and to be built, would be nearly 200,000 acres. The area at present under ditch is 52,000 acres, and there is in cultivation at this time under the Springer Ditch about 2,000 acres, under the Vermejo about 4,000 acres. There are also a number of private ditches on the open table-land at the same altitude. Their area of service it is difficult to estimate. These ditches are taken from the Cimarron, Ponil, Van Bremmer, Vermejo, and Red rivers on the New Mexico portion of the grant, but the amount of bottom land now under cultivation on these different creeks will aggregate about 30,000 acres. These are cultivated by different settlers, who have either bought or leased from the grant owners. There are in all about 300 families, or a population of 2,000 persons, not including the mountain and cañon farm lands. It embraces only the first and second bottoms on the rivers as far as they extend into the mountains, up to their head waters and down to the foothills. There are a number of other settlers in the Moreno Valley, Ponil, Van Bremmer, and Vermejo parks; but these chiefly depend on the rain which falls there abundantly at different times of the year. The total population of the Maxwell grant, including mines, different towns, farmers, etc., will now be about 7,000 persons. The total area under ditch is over 80,000 acres.

The climate, except in the high mountains, is mild for nearly every month of the year. Fine weather extends as far as the end of December, and only in January are there a few cold days. Rain falls abundantly in April and May, followed by the dry month of June; rain starts again in the months of July and August, thus affording as a rule the very best opportunity for good crops. During the winter the snowfall is moderate, but abundant enough to saturate the soil and give an opportunity for early plowing. Fall plowing has become the rule. The temperature is mild; the nights are cool even after the warmest days, and the heat in summer is never oppressive. The table-land altitude where the irrigating systems are located varies from 6,000 to 6,500 feet, while in the mountains where crops are raised it varies from 6,200 to 8,400 feet. At the latter altitude rains are abundant. The following statistics of rainfall and temperature during the year 1890 are taken from observations made by a weather station which is located at the head gate of the Vermejo Ditch, the altitude of which is of about 6,400 feet:

Rain and snow fall for 1890.

	Inches.		Inches.
January	0.00	August	2.12
February	0.00	September	0.95
March	0.90	October	0.41
April	4.67	November	0.37
May	1.30	December	0.52
June	0.46		
July	3.75	Total for year	15.45

Temperature.

Month.	Average height.	Maximum.	Minimum.
January	36.72	66	2
February	39.26	76	2
March	41.31	72	3
April	52.00	74	16
May	63.57	83	41
June	72.71	91	46
July	71.01	88	47
August	66.90	90	45
September	61.72	84	35
October	54.23	79	20
November	42.22	79	13
December	36.44	62	6
For the year	53.17	91	2

With regard to the July and August rains, a graphical presentation of the daily mean discharge in cubic feet per second of the Vermejo River for the seasons of 1889 and 1890, will illustrate their character. The floods of the Vermejo, as a rule, never begin before July. In 1889 there was a severe flood on the 11th of July, but there have been only exceptionally small floods for the same month in 1890. In 1889 there were no floods of any importance after the one on the 11th of July, but the next year there was a series of five floods, extending through the months of July, August, and as late as September; the one in September being the most important. It is therefore very difficult to draw a conclusion as to the amount of flood water that can be counted on in a certain month in the year on the Vermejo River. Summer observations have been made on the Cimarron or Springer system, but while the fall of the Vermejo River is 50 feet per mile, the fall of the Cimarron is not over 30 feet. The consequence is that the floods on the Cimarron River are not so heavy, as a rule, as those on the Vermejo; at the same time the floods on the Cimarron River, which derives its waters from much lower mountains than the Vermejo, are much earlier than on the Vermejo River, and mostly occur in May and June. It may be stated that while the snows on the Cimarron begin to melt and the waters of that river begin to come down as early as the month of March, they can not be counted on, for the waters do not come down the Vermejo earlier than the latter part of April and often not before the beginning of May. At the same time the flow from the Vermejo River lasts much longer than that from the Cimarron River, on account of the higher altitude of the mountains and the larger amount of snows on them. As a matter of fact, one season balances the other in the seasonal result. These observations extend for a period of about five years. There is no doubt felt of the ability to handle the flood waters and to store them in the open reservoirs now constructed, or to be constructed in 1891–1892, there having been such an immense quantity of snow in the mountains that all the reservoirs are brimful of melted snow. But by the time the summer floods come down a good deal of this storage water will have been used. It will always be necessary to gather in all the flood water that can be secured and store it in reservoirs.

The actual original cost of constructing the Springer and Vermejo ditch systems, including all the embankments, flumes, drops, head gates, ditches, and other works, has been as to the Vermejo system complete but $1.80 per acre; including recent improvements and extensions of lakes and embankments not planned at first, the Vermejo system has now cost $69,000, or $2.30 per acre of irrigable land. This appears in the annual report of the company. The Springer system cost $70,000, or $3.18 per acre of irrigable land. That includes the construction of an embankment along the largest reservoir of 4,400 feet in length and 26 feet high at the highest point, covering a lake surface of 475 acres, containing 219,000,000 cubic feet of water and 130,000 cubic yards of material in embankment. This embankment has cost $26,000 and is included in the total cost. All of the work has been done under contract and by hand; ditching machinery has not been used. The average cost of labor for man and team per day may be stated at from $3 to $4. The earthwork was let out by public tender. From 8 to 12 cents per cubic yard for prairie work and light shale was paid. The lands under these systems, including perpetual water rights, sell at present (1891) at from $20 to $25 per acre; $12.50 per acre was the first price. Party buying land with perpetual water right reserves for each 80 acres 1.44 cubic feet of water per second flowing over a weir, during the irrigating season, which is from the 1st of April to the 1st of November, a period of seven months.

The contract made with settlers states that the company has the right, after having sold all lands called for by the water supply, to turn over the ditch system to the owners of the land, provided the latter shall have paid in full for all rights. The company reserves to the community at large who are buying these lands the pro rata common and joint use of the reservoirs and lakes, which means that it does not allow them to irrigate by laterals direct from reservoirs to their individual lands, these reservoirs being considered as feeders of the whole system, to which nobody has a particular right but in which everybody has an undivided interest. At the same time the right is reserved of extending the system even after control has passed out of present hands, in case the water supply should prove to be so abundant that it can, by an extension, be made to irrigate an additional quantity of land.

The effect of such a system is this: First. That at the close of the period of land sale the ditches and works become the property of the owners of the land, with the reservation as stated in regard to surplus water which may be available in addition to the water supply set aside for the actual purchasers—the estimate mutually agreed upon on the Vermejo system, for instance, being that it will irrigate 30,000 acres; second, that no direct contact is permitted with reservoirs, but they are to be held as common property and feeders of the entire system; third, that if by filling up of the land, economy in the use of water, and an increase over the present calculation of the capacity of the storage basins a surplus of water is found, the right to increase the area of land to be covered by it is retained, provided the amount of water per 80 acres is supplied for which the agreement calls; the understanding being that if it be found the system will supply at any time an amount of water larger than may be needed by the 30,000 or 22,000 acres under each system, the right of claiming this surplus is to be reserved. The transfer of water rights is limited by the amount called for by the contract. It will be apparent that if the system as now existing is large enough to supply everyone under it before all the sod has been broken and all the lands have been brought under cultivation and under irrigation, there will be an excess of water available after all the lands have been, say, two or three years under cultivation and under irrigation.

The agreement stands good as to the individual for the amount stated in the contract, except as provided in article eight of the water agreements, which states that if the volume of water prove insufficient from drought or from any other cause beyond control, the company shall not be liable for any shortness of supply occasioned thereby, but shall have the right to distribute the water pro rata to the holders of the land. If, by economizing his water, the individual landowner obtains therefrom the means of increasing his area of cultivation, that is his advantage and nobody else's, and the constructions by individuals of reservoirs on their land to gather flood water is strongly encouraged. In any event, if the present system shall be found to hold more water than is now calculated upon, the advantage of that calculation exceeding the amount given to each landowner under the contract will belong to the company. The limit, therefore, to the individual landowner is the amount stated in the contract, and the amount stated in the contracts will become the property of the community ditch owners, and no more.

In regard to evaporation and seepage, it is found that the seepage in the natural lakes or reservoirs is quite insignificant; that, in fact, after the first year the lake bottoms are as tight as a pot. As to evaporation, experience leads to the idea that reports thereof are greatly exaggerated. Last year, at the end of October, there was, for instance, ten feet of water in Laguna Madre; the sun was quite powerful in that month, as well as in November, and even in the beginning of December; and after irrigating several hundred acres for plowing in the fall and spring, it was found that the water in Laguna Madre had only decreased one foot by the 1st of March. While there may be considerable evaporation in a hotter climate and a lower altitude, as in Mexico, Utah, or southern California, it is not of any importance, comparatively speaking, in an altitude of between 5,800 and 6,400 feet. Mr. L. S. Preston, engineer, proposes to make a systematic record of both the percolation or seepage and evaporation, as far as practicable. This gentleman is now keeping a record, twice a day, of the depth of water in all the lakes and the amount of water used for irrigation, and also of the amount of water that comes in at the head gate. The difference, of course, between the last two amounts will give the loss by percolation and evaporation. Percolation or seepage is, of course, a matter depending largely on the porosity of the soil. The bottoms of the reservoirs on the two systems are practically the same. It is a hard adobe clay that bears water, and after having been soaked becomes non-porous. The depth of the stratum that lies beneath has not yet been ascertained. The effect of water upon this adobe is to fill it up and make it non-porous, so that the bed becomes a stiff water-bearing bottom. In support of the opinion that the seepage is very small is the fact that in 1891 foundations were dug for a new dam to the outlet ditch at Laguna Madre. The bottom of the trench for the foundation was dug to a depth of 20 feet below the surface of the water in the lake and not over 50 feet away from the edge of the lake. It was 18 feet after the surface of the water was reached before any percolation into this trench was observed, so that the water had not penetrated more than 2 feet. This occurred on the Vermejo system, and shows that the clay must have retained water most effectually. It makes a hardpan that can not be penetrated. No depth has been found to the alluvial soil. No wells have been bored, and 30 feet is as far as has been penetrated. Fifteen thousand acres have been sold up to date under the Vermejo ditch system, and under the Springer ditch system 5,000 acres. Of land in the foothills and mountain regions, some portions of which are to be irrigated from adjacent rivers and others are under the natural rainfall, under the present administration 53,000 acres have been sold in all.

It is claimed by the manager, Mr. Pels, that the object in building these ditch systems was not only to sell the lands off rapidly, but to divide them in small holdings sufficient to support and make a good living for a family, with a view of increasing the population there as much as possible by an influx of good, thrifty settlers who would make good citizens. The experience has been that people, as a rule, in taking Government lands or in buying from private parties, buy more land than they can handle, and are just ready for a mortgage when they have to make a second payment, having no available means after they have done the work of farming, fencing, building houses and barns, etc. This has gradually and as far as possible led to a restriction of the amount of land to be bought by each individual. The consequence has been that deducting the Maxwell Land Grant farm, the average now owned by each settler's family on the Vermejo and Springer ditch systems will not exceed 80 acres. Lately it is found that the purchasers are reduced to 60 acres or less, which will give a good living to a family, and that several of the larger holders resell part of their lands. The board of trustees have made it a rule not to sell any tracts, whether on the irrigated systems or in the mountains, exceeding 320 acres to any one bona fide settler, except for establishing colonies, and have also made it a rule to exclude sales to speculators, and they limit themselves exclusively to sales to bona fide farmers. The limit per capita for farmers in this altitude and under these conditions varies. It is thought that a family can, as stated above, make a good living and become very well to do by cultivating an area not exceeding 60 acres. He can do with even less if he has the means of raising fruit only. At the same time the case is different where a man buys lands in the mountains along the streams. It has been the rule to sell at least half a mile across the stream, the buyer thus taking in, say, about one-fifth of irrigable land and four-fifths of hill land, which latter can only be used for grazing. The consequence is that people fence in these and use the hills to a great extent for raising some cattle, which industry, of course, has to be limited to a few milch cows on a 60-acre tract in the irrigated systems. This applies directly to the cultivation of the soil for crops and general farming purposes, not to the question of a timber or grass claim. Timber tracts are not sold and efforts are being made to preserve the timber at the heads of streams, to secure always an ample water supply below.

In this system there are practically three qualities of land: The tableland that lies open under the ditches, present and prospective; the high foothills, lands that consist mainly of more or less narrow valleys and the foothills just above them; and then the higher mountain land, which includes a portion of the stream and cañon region, has some timber, and which is largely a cattle range.

It is preferable, as a matter of economic growth and social life, that all the arable lands should be settled in small portions, and efforts are being made with that end in view. From general observation as to the land cultivated by irrigation it is thought to be more desirable to have small than large holdings. As a rule there is more made by cultivating intensively under irrigation of small parcels than there would be by cultivating large farms under the same system. Farming does not pay where a family has bought land and has to apply for outside help and borrow money in order to secure the means of cultivation. This does not apply to farming on a large and systematic scale as is done on the Maxwell farm under the Vermejo Ditch. A thousand acres have here been broken, of which 600 are in alfalfa, an expense which undoubtedly gives first-class returns, but which, on account of the heavy outlay for seed, preparing the soil, and ditching, can not be incurred by many individuals. Allowing the existence of large landholders with abundance of capital in one portion of the locality such as this, and then allowing for a considerable number of persons of moderate means and industrious habits and intelligence, and comparing the two systems as to the cultivation of the soil and the results thereof, and looking at it abstractly as to whether a number of small holdings are a large holding with large capital should be preferred, it is believed that the result would be, if other conditions were favorable, that the financial results of ten farms each of 60 acres, compared with one farm of 600 acres, however ably conducted, will show after a few years a decided advantage in favor of the ten farms. Experience in this matter, not only here but also in Holland, gives the conviction that small holdings of land only are conducive to a maximum of prosperity. Besides, the primary object has been to induce the settlement of as large a number of good, hard-working, law-abiding citizens as possible.

The policy adopted of having the ditches and reservoirs become the property of the community when the water rights thereunder are all sold is the result of deliberate judgment that the ownership and administration are best in the hands of the landowners; this plan has also been followed to a large extent in Colorado.

On several of the farms that are now being cultivated there are individual reservoirs. This is a matter that is to be encouraged as much as possible. Not only on these ditch systems, but farmers also who are located on the bottom lands near the rivers, have been informed by the manager of the company that its surveyor has been instructed to locate, free of expense to them, sites for them to build reservoirs on their lands. The object of this is to encourage them to make use of and gather all the flood water they possibly can, so as to drain at other times on the resources of the ditches as little as possible, and consequently to reserve to the community at large, in dry seasons and at times when there are no floods, the greatest amount of water that will run into the ditches. The concession is even contemplated of reducing the price of land to such parties as are willing to go to the expense of building small reservoirs on the lands they buy. These reservoirs will be filled by laterals built by the farmers, and which connect with the main ditch laterals or canals, and it is simply a matter of knowing in time when the floods arrive so as to open all the gates at the different laterals; and of that all are always advised in time by a telephonic system, which connects the head gate with the residence of the ditch superintendent and with other points of the system. These small individual reservoirs are encouraged, then, first as a means of holding the actual surplus of the farm laterals, and second all such surplus as may suddenly arise from floods or storms. The efficiency is doubtful, however, of any ditch system having no reservoirs and therefore not able to store and gather all the flood water and surplus of river water or of rains or cloud-bursts; only a storage system can supply its farm lands as well during the dry months as in the months during which the snow melts and the ditches run full. Attention should be called to the possible value of these small farm ponds or lakes in the course of two or three years. It will be found that, properly located upon the farm with a view to its natural condition and drainage, they will receive back from the soil a large amount of the water put into it for the purposes of irrigation, after it has fed the plant life; that they will be kept with water in them from the natural return to the center, such as a reservoir will make, of the water unconsumed by the plant life, applied to the surface for irrigation purposes. There are some very remarkable facts that come to light on that subject, and it will be worth while to observe what is suggested in regard to it incidentally; that the use of water adds to the conservation of water; that the use of water in irrigation increases the supply of water from the earth itself. As a natural consequence, if we have a proper reservoir, the unused water will also be drained into that reservoir after it has been applied on the surface, and it will be the ranchman next below who will get the benefit of this. This will be done by gravity, but very often that gravity will be sufficient, even in 80 acres, to make an impression on the reservoir of that 80 acres.

The products that do admirably well, grow profusely, and are paying crops on these ditch systems are all kinds of fruit trees, except, of course, the tropical and semitropical varieties, besides alfalfa, wheat, barley, oats, millet, sorghum, and all kinds of garden produce. A trial is being made of the culture of the sugar beet, and it is hoped that the quantity and quality of the saccharine matter may be satisfactory. On the Maxwell farm 350 acres of alfalfa was planted a year and a half ago, from which 1,000 tons will be cut this year; 250 acres more of alfalfa was sown this spring, which had a beautiful stand. In fact all the products of the temperate zone grow here in abundance. Magnificent apple, pear, prune, plum, cherry, peach, and apricot trees grow on Dawson's and Montgomery's ranches on the Lower Vermejo. All fruit trees do very well here. Their product has a fine flavor, nowhere excelled, and thousands and tens of thousands are now planted on this ditch system. Wheat never brings less than 30 bushels per acre, barley 60 bushels per acre, etc. All grain here is very heavy, especially oats, which always weighs from 40 to 45 pounds per bushel. All other grains yield in proportion. For raising hay this country is unexcelled, as the haying season is always accompanied by dry, warm weather. Alfalfa, timothy, and clover are raised in large quantities and yield enormously. Alfalfa gives three or four crops a year, producing from 1½ to 2½ tons per acre at every cutting. Potatoes, beets, turnips, parsnips, onions, and cabbages grow abundantly, and are of large size and remarkably fine flavor.

VIEWS OF MR. PELS AS TO WATER ADMINISTRATION.

In conversation with General Manager Pels, of the Maxwell grant, he expressed opinions on the administration of irrigation interests which have the weight of extensive personal observation and experience in such matters. Mr. Pels resided for several years in the Dutch East Indies, has visited India, China, and Japan, and is familiar with irrigation conditions both there and in California. What he says, then, is interesting and comes with considerable force:

> The system of incorporation known as the irrigation district system, which has grown up in California, has not been operated here. A great legal and litigious trouble arose there on the question of riparian rights and the rights of prior appropriators. Of this the manager of these systems is aware, but was uninformed of the fact that all of these troubles have been settled by a system of municipal or district incorporation under a system of laws. Under these laws the irrigators in any common district, being citizens as well as land owners and irrigators, have the right to form themselves into a municipal body, with power to bond, to hold property, to levy rates and taxes, to pay interest on bonds, to condemn property, to purchase property, and to construct works. The laws on irrigation in Colorado are well known in New Mexico, because they are likely to be adopted sooner or later in this Territory, where there is no legislation worth speaking of on water; but the peculiar system in Cali-

fornia has not been studied here. There is in New Mexico only the natural property right and the prior appropriation principle. The laws in New Mexico seem to be rather vague, but there has never been any trouble or litigation in that respect. California has adopted a system of thirty-two districts. This system has at once, within five years, stopped all litigation about riparian or prior appropriation or community rights by creating a new community interest. It simply says that the people of a community may form themselves into a district; they then find out the system of irrigation which will best serve the area of which that district is composed; they have then the power to absorb the private ditches and the corporate ditches, and they issue bonds to cover the cost of these; these bonds run twenty-one years and pay 10 per cent interest and the district becomes the owner, as a community, of the water, of course. It becomes the actual working owner of water and the works. It makes regulations and levies rates, and these rates are by law as applicable to those living within the area who do not use the water as to those who do; it being decided by the courts that the minority of nonusers are benefited to a sufficient degree to warrant the compelling of the paying of rates and the bearing of their portion of the burden of maintaining the district. Now, the effect of that has been to stop all litigation, and the effect is also to bring the larger capitalists, after some disputes, into harmony with the users of the water and to make them see that it is better to take the bonds and get the benefit and get rid of the works than it would be to hold them. Now, a principle of the same kind has been adopted, without any dispute between the landowner, water-user, and the corporation; and the same result has been reached in New Mexico, without the necessity of law, as that to which the California irrigators are coming to under the elaborate system of districts they have adopted. A water district has been practically established by which the community will some time own their own water works. And the limitations thereon are only those that increase the value of that community's interest.

Mr. Pels also expressed a desire to assist in making a presentation of irrigation systems at the Columbian World's Fair in 1893, by having photographs taken of both the ditch systems under his management, giving a comprehensive bird's-eye view of as much as possible of each system. The Agricultural Department will be supplied, he says, in time, with specimens of all the products raised under them, and with such other information as may be required, if timely notification be given. From time to time data relating to the progress of evolution in northeastern New Mexico as to the increase of the area of irrigation, the production and nature of works, and general statements that will show the progress of the cultivation of the soil in this region by irrigation will be furnished to the office of irrigation inquiry.

THE MEXICAN SYSTEM—FRUIT CULTURE IN THE MESSILA VALLEY.

The soil is all alluvial and is made up of silted mountain detritus. The products are the hardier fruits, such as peaches, pears, apples, etc. Figs may be raised, but not sufficiently to be valuable for commerce. Wheat, under fairly good cultivation, according to Prof. Hiram Hadley, of the agricultural college, averages 40 bushels to the acre, and oats are cut three times during the year from one sowing. The experiments with sugar cane show that this portion of New Mexico is one of the best known regions for its culture. Sugar beets will also thrive. From Rincon to El Paso the Rio Grande Valley is one of the finest of corn regions. All vegetables do well, and the gardeners have the advantage of putting products on the market three weeks in advance of the main crop. Asparagus grows wild when once started. This valley is the home of the grape, the Mission variety being the favorite. Near Las Cruces there are vineyards fifty years old that show no sign of wearing out. The average yield of Mission grapes is 10,000 pounds per acre. The Muscat, Alexander, Tokay, and Rose of Peru varieties are also planted and do well. Grapes from this region are on the market two weeks earlier than the California pick. Alfalfa yields an average of 4 tons per acre, averaging about 1 ton per cutting, but 2 tons per acre have been cut at once.

Irrigation at the present time is carried on under the crude Mexican community system, but the native population seem ready to adopt more advanced methods and to turn their rude acequias into large canals, provided only that their hereditary rights in the water are recognized and protected. Don Jacinto Armijo, probate judge of Donna Ana County, speaking for the native irrigators, desires that the ditches should be taken out by improved machinery and not by manual labor, and further declares that the people are seeking to prepare their land after the method practiced by the agricultural college at Las Cruces, and that since the establishment of that institution a general and very material improvement has been observed among the Mexican irrigators. He thinks that if the supply of water were regulated by a just corporation, assuring to the people their rights to water, or the whole placed in the hands of a system like the California irrigation districts, instead of the present community method, the people would readily accept the situation and turn over their present ownership to the better administration of a larger autonomy. The great obstacle to such an arrangement would be the opposition of the small irrigators, who, having no money to maintain their ditches, pay for their water by manual labor. These would not favor any change of system, except on the most absolute assurance of security. It is easier, he says, for these small farmers to pay ten days' labor than $5 as a tax. The district system would meet their wants.

The records of the acequias under the mayor domo's shows the following acreage in Donna Ana County that received water during the year ended June 30, 1890, and that the same was cultivated by 810 irrigators, three-fourths of whom, or 620 persons, are Mexicans:

Las Cruces, 120 terrenos of 50 acres each	6,000
Donna Ana, 50 terrenos of 100 acres each	5,000
Messila, 200 terrenos of 52 acres each	10,400
St. Thomas and San Miguel, 40 terrenos of 50 acres each	2,000
La Mesa,* 100 terrenos of 40 acres each	4,000
Chamberino, 40 terrenos of 50 acres each	2,000
La Union, 80 terrenos of 50 acres each	4,000
	33,400

At Colorado and Santa Theresa and from Rincon south toward Donna Ana there are 2,000 more acres. In Toulerosa, including Three Rivers, there are 2,000 acres, thus making a total of 40,400 acres watered in Donna Ana, of which over 90 per cent was actually cultivated during the year ended June 30, 1890. This estimate is very conservative and somewhat below the actual figures of cultivation by irrigation in this county. Land entitled to water in this region is too valuable to lie idle; besides, if a few large ranchers of 4 to 2 terrenos of land be excluded, the average size of the farms in Donna Ana County will be about 20 acres, all of which are intensely cultivated.

Col. Albert J. Fountain, a well-known lawyer, and a gentleman who has made a very close study of old and modern New Mexican life, says:

> The district system of irrigation as practised in California is the only innovation that the people would be likely to tolerate on the present method of community ownership of water. Their right of water runs with the land under the Mexican law; and while the system is cumbersome, yet it insures the people their water; any system that makes them pay money for what God has furnished is incomprehen-

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* Originally La Mesa had but 50 terrenos of 40 acres each or 2,000 acres.

sible to them. They are willing to work to build ditches and develop water, but refuse to be taxed a cent in money. If they could be brought to understand that a better system would provide their water, preserving to them all vested rights, little objection would be offered. The old Spanish dictum was that the water owed a beneficial servitude to the land, and that the sovereignty of the Government over the water was for the purpose of assuring the service. Any system, whether it be a municipal or private corporation that seeks authority at the hands of the native people of this Territory to exercise direct or indirect control over water, conflicts with the hereditary idea of sovereign governmental ownership in water for the benefit of the community of landowners. Then, again, the people fear a clash between the old legalities guaranteed to the native population by treaty and any new authority that may be created. The system now generally proposed is about as follows: We have 120 terrenos or 6,000 acres of land under cultivation in and around Las Cruces, divided among 300 or 400 persons, some of whom own 5 acres, some 100 acres or more. Under the present plan each one of these persons is required to contribute, either in labor or money, a sufficient amount pro rata to keep up the assessment for repairs. The proposition is that all of these people—and there can be no corporation unless it be unanimous—that all these people surrender their water right to certain persons, whom they shall elect as their directors, receiving in return a certain amount of stock pro rata for these rights in lieu of their present direct ownership. The amount of stock each would own would be taxed a proportionate amount to keep up the acequia. Suppose I own 5 acres, and it is put into the stock fund as $500 worth of stock. I would be required to pay 1 per cent in order to keep up the acequia. The capitalization being $100 per acre, that would be $5 per annum, and $6,000 from the whole amount of land. This sum would of course be in money, and that is the great objection. The ordinary native is willing to contribute three or four days' labor per year, but he is very loath to pay even the smallest sum of money in lieu of that labor, because his ancestors always had their water by labor, and he can not see why he should pay for what he considers his by vested right. The objection is to the method of administration and not to the merits of the proposition. Another difficulty is that this scheme does not recommend itself to the English-speaking promoters of irrigation enterprises or capitalists. The people would be the only beneficiaries by this plan, gaining thereby the power to turn 6,000 days' labor into, say, $6,000, and from this fund through their district supervisors or commissioners, purchase proper machinery, and thus lower the future cost of irrigation, besides having their work better done.

Another proposition is to take out a large ditch by private enterprise, starting some miles from the present head gate. This is to furnish water at a low rate to all who surrender their water to the ditch company. The people look on this with suspicion. However, it may be said that if these people take out their ditch without interfering with anybody else, it would be a great advantage to irrigation in this region; and it is a practical proposition, especially if they adapt their canal to the irrigation of the mesa lands. The Procita grant of 13,000 acres, just below here on the mesa, offers a very good opportunity for the investment of private capital in such a canal, and the people would offer no interference whatever. There is also a very large acreage of new land outside of their grant on which the capitalist may expend his energy to his commercial profit and the great advantage of local irrigation. The main street of Las Cruces is 20 feet above the highest ditch line, but between the town and the foothills lies a wide acreage unequalled for the production of the wine and raisin grape. Every acre of this land is worth $50, and the proposition to water it is feasible; therefore, when the ditch men come to the present owners of water rights to negotiate for their ownership, it creates suspicion in the minds of the people. * * *

In connection with the statistics presented lately by the Census Office in its bulletin on "Irrigation in New Mexico," I would like to say, and desire to be quoted, that I do not know or care where the office got its figures, they are wrong and a grave injustice to our people. The number of irrigators in this county, according to the records of election of the mayor domos, at which no one can vote unless he is an actual irrigator, for the election prior to June 30, 1890, was 810; and there are 40,000 acres in all cultivated. It is too much to say that 10 per cent of this land is uncultivated or not irrigated. Land with a water right is too valuable. As to size of farms I want to say that the largest irrigator is the "townsite company," that irrigates 600 acres. There are not a great many tracts larger than 40 acres and the average extent of an irrigated farm will be about 20 acres. As to crop values per acre, I want to say that alfalfa will bring $80 to the acre. Wheat and corn are low in average, about $20 per acre. Corn will bring $36, and grapes at 2 cents per pound will net $200 per acre. An acre of grapes or 700 vines averaging 20 pounds to the vine will at 2 cents a pound pay $280. The finer varieties, such as the Muskat and Tokay, will average per year $300 per acre. Two years ago I know they brought $600 per acre. These are facts and presented to enforce my estimate $200 per acre for grapes. Alfalfa, on June 30, 1890, was worth $15 per cured bale. In the early spring it was worth $20, and $9.50 was the lowest price paid during the year considered. These figures will hold good throughout the Messila Valley.

The Mesilla Valley, as dominated by the Organ Mountains, is believed to be underlaid with phreatic water. Considered in connection with the the surface supply, this will largely supplement the acreage now under cultivation. Dr. Alphonse Petin, of Las Cruces, in discussing the movement of the underflow in this valley, says that on his place, about 1½ mile out of Las Cruces, he dug a test hole 14 feet deep and 6 feet wide. At 12 feet 6 inches very coarse, black volcanic sand was found and on reaching 14 feet excavation could not be continued without planking because the water ran through the stratum so readily. He said:

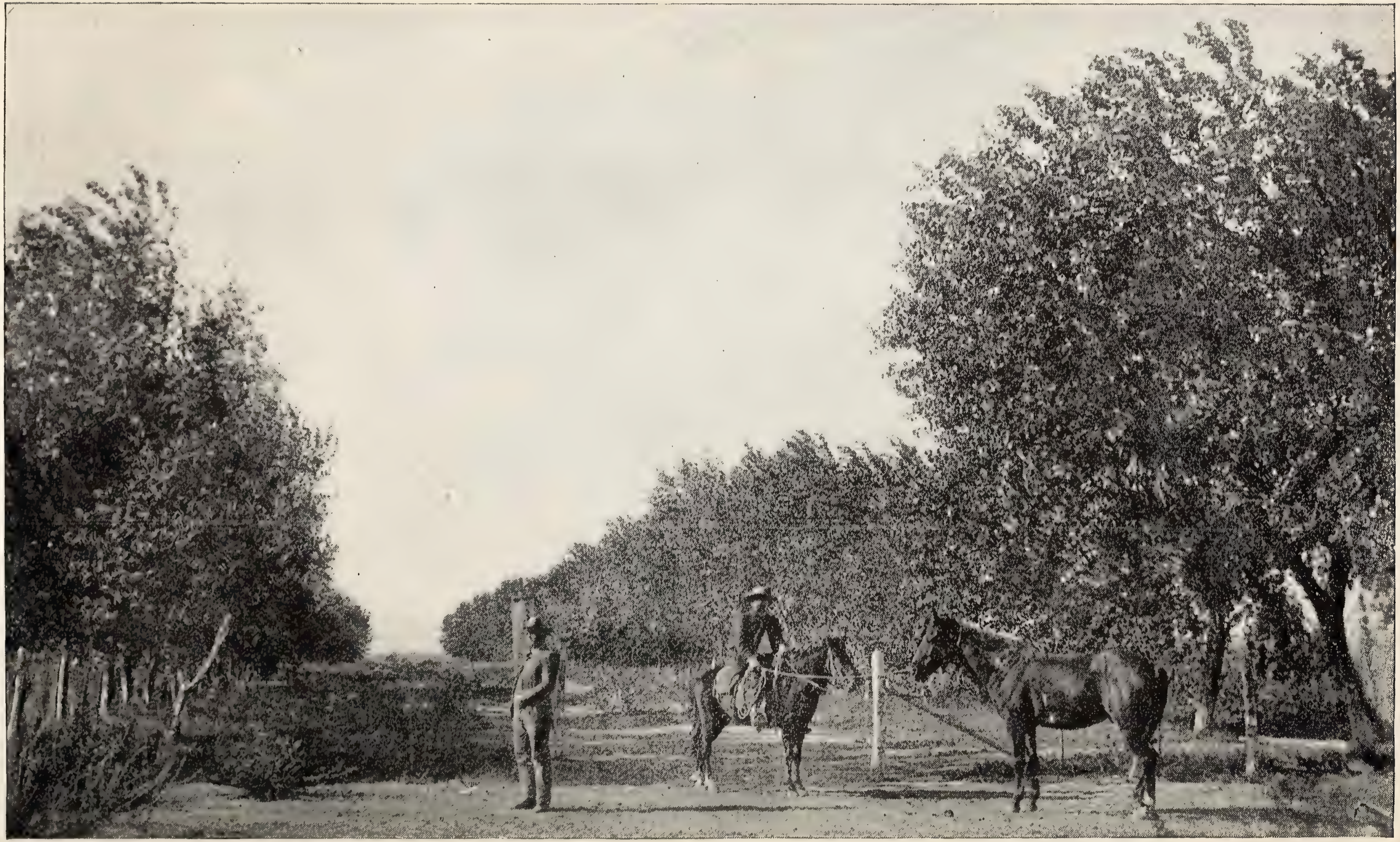
> I then tried the experiment of dropping a piece of paper on the north of the hole and it floated to the south side in 2 minutes and 45 seconds. I repeated that experiment for two days until the hole caved in and noticed that the float crossed the 6-foot space more quickly on the second day by about 15 seconds, or in 2 minutes and 30 seconds. These experiments were carefully timed. This hole was not sunk in the river bed, but in a branch that went round a mound of sand.

On the mesa there are different flows of this sheet water, as can be seen in working for driven wells. The shallowest depth at which water is found, according to local experience, is 12 feet, and the deepest that is known of is 72 feet and 74 feet, but generally after a depth of 60 feet is reached the water rises to within 2 or 3 feet of the surface. There have been no observation of precipitations on the Organ Mountains and no means of estimating the rainfall. However, 18 feet of water has risen in a dry arroyo from a cloud-burst, so that the precipitation must be immense.

The plain or valley to the east of the Organ Mountains is entirely riverless, and has but a few springs. Near the white gypsum sand the water is very bad. This interval is over 50 miles wide with large deposits of gypsum, and in the white sand water can be found often at 2 feet. The evidence of a lost river is very apparent. The water near the surface in these beds is nearly as saline as Salt Lake, but the water from the black sand is pure and potable. The eruption that caused the disturbance here is about 700 years old. If a proper administrative or legislative policy were adopted plenty of water could be developed from the underflow to reclaim large areas of this country for pastoral purposes, at least. If this land, on which water would be very expensive for irrigation, was leased for pasture, sufficient water could be developed to support the stock. For instance, a stockman formed a tank on the plains, about 40 acres in extent, which has 12 feet of water in the center.

In the Mesilla Valley when cultivation has continued for a long time soil water is found most often at 10 feet below the surface, and a drive well will always have constant water at 26 feet. When you drive a pipe the first water is reached at about 10 or 14 feet in black, volcanic sand; then a very hard stratum for about 8 feet, below which an immense supply of water is found. Wells have also gone down 70 or 80 feet, developing fine soft water, which rises in the well.

Mr. S. B. Newcomb, of Las Cruces, also very familiar with this valley, states that long experience justified the assertion that the permanency of this water was assured, and the supply apparently inexhaustible. On the majority of the farms the acequia water was used for domestic purposes, there being no better water if you clarify it, as it is the melted mountain snow.



Irrigated Orchard near Roswell, Rio Pecos, Southeastern New Mexico.

THE PECOS VALLEY.

The chief engineer of the artesian and underflow investigation, in his final report, very fully covers the characteristics of a large section opening up under the construction of irrigation works, which promises to furnish very rapidly desirable homes for a considerable body of people. It is a valley of large extent, great fertility of soil, exceedingly picturesque and in its upper portion promises to become one of the wonderlands of the world; with an excellent climate, in the very center of the beet-sugar belt, and so sheltered as to have the advantage of a spring two weeks earlier even than the southern coast and San Joaquin counties of California. The water supply is abundant, the current of the Pecos being about 4 miles per hour with a flow at low stage of 1,000 second-feet. The works already constructed, or in process of rapid completion, are designed to serve at least 260,000 acres, and are so planned as to provide for a considerable extension. The area in New Mexico may readily be increased to 700,000 acres. The organizers of this enterprise have also constructed a valley railroad of 80 miles in length and built up, among other important improvements, a handsome town. The Pecos Valley and works was made the subject of critical study by the special agent during his tour of inquiry in the summer of 1891. The works required are on a large scale and the construction has evidently been thorough and workmanlike.

The northern canal is taken out at a point on the Hondo River near Roswell, N. Mex., the water at the intake of the canal being raised 15 feet by a frame dam resting on a foundation of closely-driven piles between which is carefully-tamped broken rock. The frame dam is 30 feet wide and 116 feet long, connecting at either end with earthen banks, riprapped with from 2 to 3 feet of rock. The canal is constructed (September) a distance of 26 miles, 30 feet wide on bottom, 7 feet deep, side slopes of 1½ to 1; it has a fall of 12 inches per mile and carries at its full capacity 6 feet of water. The maximum discharge is 561 cubic feet per second. In connection with the main canal there are thus far constructed 50 miles of lateral ditches from 4 to 10 feet wide on bottom and 2 feet deep. The northern canal as completed will water 44,000 square acres and under the proposed extension 58,000 square acres more, making a total acreage on the northern canal when completed of 102,000.

The dam of the southern canal is located about 6 miles north of the town of Eddy, at a point where the Pecos River has cut its course through solid limestone formation, giving an exceptionally favorable site. The dam is constructed of a loose or broken rock fill or embankment 1,130 feet long, 50 feet high at the deepest place, and rests on solid rock foundation the entire distance across its base. The back or down stream slope of the rock fill is 1 to 1, that of the upstream slope being one-half to 1, and carefully laid by hand. The front of the rock embankment is faced with sacked earth, gravel, boughs, and loose earth until the water front has assumed a slope of 3 to 1, this being finally riprapped with 18 inches of broken rock. The crown of dam is 24 feet wide. Near the eastern end of the dam is the scour gate, 4 by 8 feet in the clear, and built of masonry. Spillways to carry off flood waters have been blasted out of the solid rock near both ends of the dam, one being 13 feet by 210 feet, and the other 250 feet by 5 feet. The outlet is a cut 30 feet wide, 25 feet deep, and cut through the sold rock on the easterly side of the river, with gates about midway to regulate the flow of water. On the west side of the river and reservoir the limestone ridge curves around to the north and toward the river above; and some 400 yards from the center of the dam a broad cut has been made across it, 5 feet below the level of the crest of the dam, for the escape of surplus water in case of sudden rise, which water will flow down a ravine back of the solid rock ridge and reënter the river half a mile below. On the east side the ridge broadens out northward and has been cut in two by the river until a vertical cliff of considerable height has been formed. Against this cliff the force of the flow for 2 miles above comes squarely, and being broken by the solid hill, turns toward the dam a few hundred feet below. The lake or reservoir formed by the dam is 7 miles long, 1¾ miles wide, and holds about 1,000,000,000 cubic feet of water, enough to supply the ditch with a full head for nearly one month. When filled it gives a head of water 20 feet above the bottom of the cut through which the main canal is fed, and 13 feet above the feed gates when open.

There are three canals, two on the east side of the river. The Hagerman has its head dam 15 miles below Eddy, a large storage reservoir on its course, forming an extensive lake 1½ miles long and one-half mile wide with an average depth of 25 feet. The main canal is to be extended to a total length of 25 miles, crossing by a flume to the west side of the Pecos, at a point about midway between Black River and the Delaware, and continuing southward across the last-named stream to the Texas line. A third canal is under way below the Territorial line. Other operations are in progress in Chaves County, and from part of the reclamation of the Pecos Valley by irrigation.

Under date of September 12, 1891, Charles B. Eddy, of Eddy, N. Mex., wrote the office of Irrigation Inquiry as follows:

> In regard to the acreage put into agriculture and fruit-growing I can not give very accurate data, as the country is developing very fast, and any statement would lose its value.
>
> I will say, however, that we have at present deeded over 25,000 acres of water to actual owners of land. These are bona fide payers of our water rental, and additional water rental is being taken every day. Our canal was not completed so as to furnish wate until early this year, and consequently the showing as to the crops can not be a very large one for the past year, but settlers are everywhere up and down the valley clearing, grubbing and plowing their land, and thousands of acres of new lands will be sown this fall so as to produce crops early next spring. Owing to the delay in getting the canal in shape to deliver water, no effort was made to induce immigration until about the 1st of last March, when a small organization was started for that purpose. Since that date over 3,000 inquiries have been received from parties all over the county who wish to make a change of home. Settlers are now daily coming in, and from all the information received the Southwestern country will certainly receive a very large immigration this fall and winter, of which the Pecos Valley will get a good share.

From responsible parties at the same point the following statements relative to the growth exhibited there by means of cultivation under irrigation have been received. As the Pecos Valley is a new field and one of great importance, these illustrations of successful growth are given:

For instance, Thomas Stokes, of Eddy, N. Mex., raised during the summer of 1891 11 tons of sorghum (hay) on less than 2 acres of new ground, which product he sold at $15 a ton, the cash yield being over $83 an acre. Julian Smith, of Lookout, Eddy County, N. Mex., sold during 1891, during the past nine months, over $300 worth of garden produce from half an acre of ground, and has 400 pounds of potatoes left. R. M. Gilbert, whose address is Seven Rivers, Eddy County, planted in the spring of 1891 1 acre in potatoes, and gave them no fur-

Rock Cut on Curve Pioneer Canal, West Valley Line, Pecos County, Texas.

ther attention whatever except to irrigate them occasionally during the summer. When he dug them the yield was over 7,000 pounds. They sold at 2 cents a pound, so that the cash yield from this 1 acre was over $200. Mr. Gilbert stated that he can raise twice this quantity of potatoes to the acre with proper cultivation.

W. W. Paul, of Lower Penasco, N. Mex., raised 211 bushels of oats on 2⅗ acres of ground. Oats are selling here for 70 cents a bushel. Cash yield, $67 an acre. G. W. Blankenship, of Eddy, sowed 12 acres of rye on September 18, 1890; cut in May, 1891; sowed millet on the same ground and cut two crops, the last on September 12, 1891, making three crops within the twelve months. The total product in cash yielded $64 an acre. John W. Poe, of Roswell, cut 600 tons of alfalfa from 110 acres. This, valued at $15 a ton, was $9,000; cash yield per acre, $80. Maynard Sharpe, of Eddy, sold $75 worth of watermelons from one-eighth of an acre of ground. An acre at this rate would have yielded $600. He raised a second crop on the same ground, but being pressed for help did not market any of it. L. M. Holt, of Eddy County, raised 11¼ tons of sorghum on 1½ acres, and 450 tons of alfalfa on 90 acres. The alfalfa would be sold at $15 a ton, making a return of $112.50 an acre.

C. W. Greene, jr., and Sam Hughes, of Eddy, raised sugar beets that have yielded 19 and 63 tons to the acre, respectively. Samples have been analyzed at the Agricultural Department, and Prof. H. W. Wiley, the chemist, estimates the probable yield of sugar from an acre of such beets at 2,000 pounds and 8,400 pounds, respectively. Negotiations are now in progress for the building of a beet-sugar factory at Eddy.

The security to stock-raising which the development of water supplies, under irrigation enterprise, has produced, is illustrated by the fact that over 500,000 pounds of wool have been shipped from Eddy since June, 1891. It is estimated that more than 1,000,000 pounds will be shipped in the following year. George Blankenship and Edward Scroggins, of Eddy, have raised fine fields of cotton during the season of 1891. Many of the stalks bore 60 to 90 bolls each. Such results can be obtained only under irrigation; they are impossible in any portion of the rain belt.

The following table shows growth made by various fruit trees, shade trees, grapevines, etc., during the past summer:

Name and address of grower.	Tree or vine.	Growth.	
		Ft.	*In.*
Witt Bros., Eddy, N. Mex	Raisin grape	16	9
Do	Apple	4	9
Do	Pear	4	8
Do	Plum	5	9½
Do	Cherry	1	9
Do	Crab apple	1	8½
Do	Mulberry	1	8
F. G. Campbell, Eddy, N. Mex	Black locust	8	7
G. W. Blankenship, Eddy, N. Mex	Apple	3	11
Do	Apricot	5	8
Do	Peach	3	9
Do	Box elder	6	1
Do	Mulberry	7	8
Do	Lombardy poplar	6	2
Do	Castor bean	8	4
James Hogg, Seven Rivers	Peach	7	2
Do	Cottonwood	16	3
R. M. Gilbert, Seven Rivers	Osage orange	14	7
Do	Native willow	16	5
Do	Pecan	6	2
Do	Black walnut	4	11
Do	Plum	8	1
Do	Mulberry	6	4

Witt Brothers have several cottonwoods 9 years old that are 62 to 64 inches in circumference, and over 60 feet high. Mr. Hogg has a peach tree 3 years old from the seed that is 3½ inches in diameter and 17 feet 5 inches high. He has a cottonwood that is 4 years old that is 28 inches in circumference. Mr. Gilbert has a pecan tree 6 years old that is 24 inches in circumference, and 22 feet high. He has a black walnut tree 3 years old, from the seed, that is 12 inches in circumference, 11 feet 10 inches high, and that bore several walnuts this year. Maynard Sharpe, of Eddy, has two peach trees 2 years old from the seed, that bore and matured seven peaches this year. He has one apple tree 2 years old from the seed that bore three apples the past season. These facts and figures have been compiled with great care, and the measurements are absolutely correct, as correspondence with any of the parties will make apparent.

UNDERFLOW WORKS.

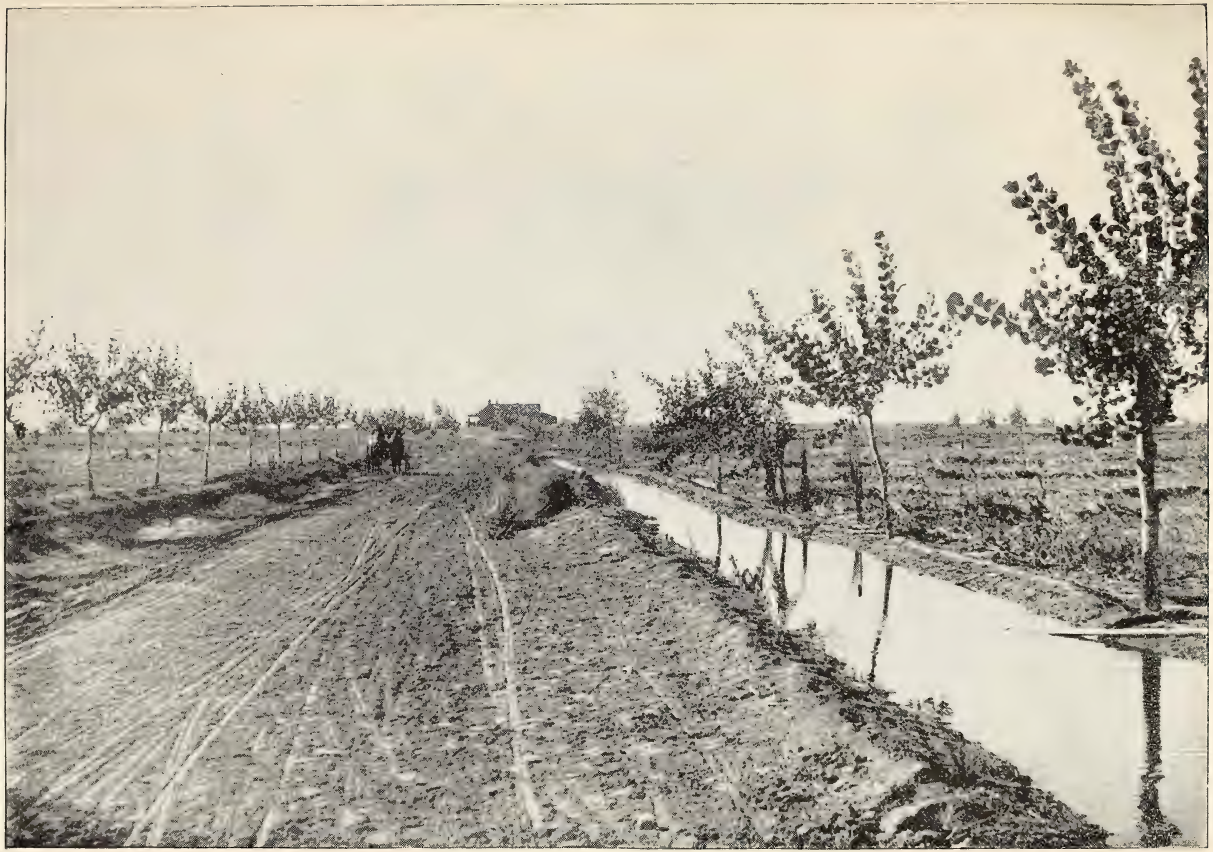
The Mimbres River heads in the Black range in the northeastern part of Grant County, N. Mex., and flows in a southerly direction. During the flood season its waters flow to a point some 10 or 12 miles southeasterly from Deming a distance of about 90 miles from its source before sinking, but during the dryer portions of the year they disappear in an underground channel at a point about 40 miles from its source. The lands proposed to be irrigated are a portion of an extensive plain extending from the proposed reservoir sites for 60 miles south to the Mexican border. This plain is transversed by three lines of railroad, the Atchison, Topeka and Santa Fe, the Southern Pacific, the Deming, Silver City and Pacific, and a proposed line now partially graded to connect Deming with important Mexican points on the south. This tract is considered to be the only agricultural land that can be made available from the Rio Grande on the east to the Rio Gila on the west, a distance of 200 miles. This enterprise and another one of a similar character in the same section are important as experiments, and for that reason the following account is given.

According to Mr. L. Clapp, jr., of Las Cruces, the civil engineer in charge of the enterprise:

> The flow of the stream was found to be 90 cubic feet per second, by measurement taken on March 14, 1891; about five weeks later it was found to be the same; on another visit in May it was estimated at one-half, and I believe that a fair estimate of the average discharge of the river at the point selected would be 90 cubic feet per second, exclusive of flood waters. This would give an annual discharge of 2,838,240,000 cubic feet.

The river bottom proper is here 900 feet wide. It shows indications of being frequently flooded from 1 to 3 feet deep. Mr. Clark says he was informed that the bottom is covered about one month on an average during each year. Assuming that this only holds good for twenty days, there will be a discharge of 5,184,000,000 cubic feet to be added to the normal total given, making 8,022,240,000 cubic feet as total annual discharge of the surface flow.

The indications for a large underflow are exceptionally good. The lower Mimbres is believed to be an underground river; in that case the surface water is only the surplus appearing after the underground channel is surcharged. Soundings taken across the valley at King's ranch show the bed rock to be from 8 to 12 feet below the surface; lying on the bed rock a layer of course gravel and bowlders from 2 to 4 feet in thickness are found, then sand and gravel from 3 to 4 feet



Residence and Orchard near Eddy, New Mexico.

Trees all planted in 1890.

and surface soil from 4 to 6 feet in thickness. The average depth of bed rock from the surface is 11 feet, and the average depth of this water, bearing stratum is 7 feet. At a width of 4,000 feet Mr. Clark estimates a cross sectional area of 28,000 square feet. Assmming this to be 20 per cent water, we have 5,600 square feet cross sectional area of the underground stream; and a flow of 1-100 foot per second would give a discharge of 56 cubic feet per second, or 1,766,016,000 cubic feet per annum; this added to the quantity previously estimated would give a total annual discharge from all sources of 9,788,256,000 cubic feet, or 224,710 acre-feet.

The drainage area of the Mimbres River from its sources to the point selected for the proposed work is at least 500 square miles, and the average annual rainfall at Fort Bayard in the foothills of the Black Range is 21 inches. But the rainfall in the mountains at the source of the river is considerably more than this. Going down the valley it decreases until at Deming, on the plains, an average of but 10 inches is recorded. Mr. Clark therefore assumes 20 inches as a fair average for that portion of the valley tributary to the system.

"Drainage ditches," says Mr. Clark, "show a small but constant flow, and with this result from the surface of the water-bearing strata there are the strongest reasons for believing that the result to be expected from a bed-rock dam, bringing all the water to the surface, will be equal to or much greater than the estimate made."

Again, the large number of wells scattered the whole length of the valley and on the plains on either side, especially at Deming and in its vicinity, show a large body of water to be present near the surface, something very unusual on similar plains in the arid regions. The wells at Deming average about 40 feet in depth and up to date seem inexhaustible, showing no difference in volume during different seasons of the year or different years, indicating a constant and uniform flow.

ANSWERS FROM CORRESPONDENTS.

The following data have been compiled from answers received to circulars sent by this office:

DONNA ANA COUNTY.

Las Cruces (post-office), Dr. Alphonse Petin and A. E. Blount (October, 1891):

Average cost per acre in vicinity for preparing land for cultivation under irrigation, from $4.50 to $25; in the valley, where mesquite grows, $7; on the mesa, $4.50.
Average cost per acre for irrigation works, ditches, etc.: On level lands, from 50 cents to $2; from $1 to $2.50 on rolling land.
Cost per acre for annual maintenance and repairs, 25 cents to $1.
Area under ditch, 21,000 acres; Las Cruces, 7,000 acres; Donna Ana and Messilla, 14,000 acres. A. E. Blount reports 90 acres under his own or neighborhood system.
Products: Alfalfa, fruits, grapes, wheat, oats, corn, barley, and vegetables.
Value of product per acre: Cereals and alfalfa, net, $20 to $25; crops separate from grazing or forage, $15 to $20.

GRANT COUNTY.

Deming (post-office), R. S. Coryell (September, 1891):

All irrigation in neighborhood done by means of water raised by means of windmills from wells averaging 50 feet deep, and each irrigating an average of 1 acre, the general product being either fruits or vegetables.
Average cost per acre for preparing such land for cultivation, $5.
Average cost per acre for maintenance and repairs, $1.
Average value of such product per acre, $100 to $250.

L. Clapp, jr., C. E., of Las Cruces (September, 1891):

Lands along the Rio Mimbres, southwest section, especially adapted to fruit growing, which is also the best paying product. Local systems of irrigation are of poor construction, apportionment of water inaccurate, and its use extremely wasteful. The main problem is one of storage, covering 2,000 acres, with estimated storage capacity of 40,000 acre-feet of water; there are also in vicinity two arroyas available for storage of about 6,500 acre-feet, giving a total storage capacity of 46,500 acre-feet. Storage is needed for supply only for certain months, and by proper regulation of distribution and use the net irrigating capacity would be 60,000 acre feet, after deducting 25 per cent for seeppage and evaporation and 10 per cent for the time when only a partial supply is drawn.

Estimated cost of the works necessary would make the cost per acre-foot of water $6.45, or not to exceed $7. This would not be excessive, as similar lands, 75 miles east, with water rights, are valued at $50 to $125 per acre.

[The project reported by Mr. Clapp as in process of development seeks to utilize the Rio Mimbres at the point to the north of Deming, where the river disappears from the surface. It is estimated that by reaching bed rock and constructing an earth and rock dam a reservoir can be constructed.]

SAN JUAN COUNTY.

Bloomfield (post-office), Lewis R. E. Paulin (September 17, 1891):

"San Juan South Side Canal Company": Water supply, San Juan River; unlimited supply.

Works: 12 miles main ditch; 10 feet on bottom, 14 feet on top, decreasing as water is drawn out; two head gates; two overflow gates; a number of underflow gates (for sluicing out sand). No reservoirs or dams.

Cost of main ditch, about $13,000.

Area under ditch, 4,100 acres tillable land; other rough land, 1,300 acres.

Area under cultivation, 440 acres.

Cost of water supply to user per acre, $15.

Annual rental cost, $1.50 per acre.

Farmington (post-office), William Locke (September, 1891):

Water supply: Las Animas River.

Works: 6 miles main ditch; 7 feet on botton; no reservoirs or dams.

Cost per mile of ditches, about $400.

Area under ditch, 1,140 acres.

Area under cultivation, 600 acres.

Cost of water supply to user per year, $4.

[No artesian wells in locality; all irrigation done by ditches from streams.]

Farmington (post-office), C. H. McHenry (September, 1891):

Chief water supply: Las Animas River; length of main branch, 110 miles; average fall, 25 feet per mile; average width, 100 yards.

Mileage of ditches: About 100 miles of ditches taken out of Las Animas River; main ditches, top 6 feet, bottom 4 feet; no reservoirs or dams.

Average cost per mile of ditches, about $500.

Area under ditch, about 320 acres for each mile of ditch.

Area under cultivation, about 160 acres for each mile of ditch.

Cost of water supply to user per acre, $1; annual rental cost, $1.

SAN MIGUEL COUNTY.

Las Vegas (post-office), J. A. La Rue (September 24, 1891):

Water supply: Mountain streams (subject to floods; at lowest stage from 500 to 600 inches).

Works: 13 miles main ditches, 2 feet on bottom, 4 feet on top; laterals fully as many miles; small rock dams, which are frequently destroyed by the floods; no head gates or reservoirs.

Area under ditch, about 5,000 acres; under cultivation, 500 acres (not more than one-half the area under ditch fit for cultivation).

Average cost per acre for irrigation works in neighborhood, from $2.50 to $4 (works generally crude and unstable).

Average cost per acre for preparing land for cultivation by irrigation: Experience of writer in irrigation confined to narrow valley of mountain stream where the area of arable land is small compared to the area under ditch; cost him $5 per acre to level and irrigate his land.

Cost per acre for annual maintenance and repairs in locality, $1 to $1.50.
Chief products under irrigation: Principally alfalfa, some corn, and vegetables.
Yield of alfalfa per acre, 3 tons.

Las Vegas (post-office), The New Mexico Land and Irrigation Company.

Water supply: Canadian River Irrigation Works; about 15 miles ditches, varying sizes, commencing about 20 by 15 by 4.
One dam 100 feet long, 15 feet high, one head gate.
Area under ditch, 3,000 to 4,000 acres. Under cultivation, 500 acres. (Company has prepared for cultivation by irrigation about 1,500 acres of bottom lands heavily covered with sacaton, at a cost of about $1 per acre for clearing.)
Estimated cost of works, ditches, etc., per acre under this system, $10.
Products: Alfalfa, corn, sorghum, and oats.

[Company has in view the construction of several other irrigation plants (the Angostura plant already constructed); also propose construction of several surface-water reservoirs, to irrigate from 300 to 1,000 acres each, and inclose map, etc., of their works.]

Las Vegas (post-office), E. F. Hobart (Santa Fé), engineer (U. S. surveyor-general); Gallinas Canal, Water Storage and Irrigation Company (September 8, 1891).
Water supply, 1,000 inches from Gallinas River (at Las Vegas Hot Springs).
Works: Dam 5 feet high, 100 feet long; 6 miles ditches 2½ feet deep, 5 feet wide at bottom; fall 6 feet per mile; one reservoir, area 30 acres, formed by embankment 15 feet high, one-half mile long.
Cost per mile of ditch, $400 (6 miles, $2,400); cost of reservoir, etc., $2,600; total, $5,000.
Area under ditch, 5,000 acres; under cultivation, 500 acres.
Cost of water supply to uses per acre, $10.
Also, Onava Canal Company (Las Vegas), E. F. Hobart, engineer.
Average cost per acre for preparing land for cultivation, $5 (breaking, $3.50; fencing, $1.50).
Average cost per acre for irrigation works, ditches, etc., $2 to $5.
" " " " " maintenance and repairs, $1.
Staple products, at Santa Fe, all fruits of temperate zone.
Staple products, at Las Vegas, all grain, etc., of temperate zone.
Value of products per acre: Fruit, $400; grain, etc., $40.

Census Bulletin No. 60, F. H. Newell, special agent, gives the following statistics:

Number of farms	4,174
Number of farms irrigated	3,085
Average size of farms irrigated (acres)	30
Average annual value of products	$12.80
Irrigated area (total) in acres	91,745

NOTE.—Dona Ana County, 275 irrigators; 11,051 acres irrigated; 130 acres average size of farms; $8.82 average value of irrigated product. Santa Fé County, 123 irrigators; 1,358 acres irrigated; 11 acres average size of farms; $14.22 average value of irrigated product.

NEVADA.

This State occupies an elevated plateau in the northwestern portion of the Great Basin, bounded on the west by the Sierra Nevada Mountains, and on the east by the Wasatch range and the Salt Lake Basin. It has an altitude above sea level of from 800 feet, at its southeast boundary on the Colorado River, to nearly 7,000 feet at its northern boundary, averaging about 4,000 feet. It is traversed in a northerly and southerly direction by high parallel ranges of mountains, some attaining to the height of nearly 12,000 feet above sea level. These are separated by valleys varying in width from 5 to 25 miles. Some of the valleys are broad depressions or sinks, which, during wet seasons, are partially overrun by water and form shallow lakes. During the summer season these become dry and seem to be alkali flats and desert wastes; they are, however, valuable for their deposits of mineral salts, etc.

Its boundaries commence at the northwest corner of Utah Territory, and the southern line of Idaho at the intersection of the thirty-seventh degree of longitude west from Washington (114° 3′ 0.57″ west from Greenwich), and in latitude 42° north; thence running west along the southern line of Idaho and Oregon to longitude 43° west from Washington (120° 3′ 0.57″ west from Greenwich); thence south along the eastern line of California to latitude 39° north, which falls in the southeastern part of Lake Tahoe; thence southeasterly along the California line to the point of intersection with the Colorado River, in latitude 35° north, and opposite Fort Mojave; thence north and easterly up the center of the Colorado River to its intersection with the thirty-seventh degree of longitude west from Washington, which is the western line of Utah Territory; thence north along the said western line of Utah Territory to the place of beginning, containing within the said above-described boundaries 112,090 square miles, or 71,737,600 acres. An approximate classification of this area gives the following divisions:

[From State Surveyor-General's Report, 1890.]

	Acres.
Water area	1, 081, 600
Forestry[*]	2, 000, 000
Grazing	30, 000, 000
Agricultural lands[†]	20, 000, 000
Mineral lands	15, 000, 000
Saline, borax, niter and sulphur deposits, alkali flats and deserts	3, 656, 000
Total	71, 737, 600

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[*] Compiled from the report of Commissioner General Land Office for 1887.

[†] The agricultural areas may be subdivided as follows: Irrigable lands, about 6,000,000 acres; non-irrigable lands, about 14,000,000 acres.

The State surveyor-general says of the climate that the State—

> lies in a belt that contains all temperatures, from that required to grow cotton and cane to that necessary to the hardening of oak or ash. Through all sections there prevails that dryness of atmosphere peculiar to this region. In the absence of dews and moisture malaria does not exist in this clear, dry atmosphere. The days are mild and pleasant; the sunshine, so clear and bright, gives cheerfulness everywhere. The nights are cool and invigorating; never sultry or close. On account of the lack of humidity, the extremes of heat and cold are not so perceptible as in moist climates. No heat is oppressive in any part of the State. Summer evenings are always cool and pleasant, and serve as a tonic for the following day. In winter the mercury falls at times to zero, and in some localities much below, but with all that the winters are never severe, and many days—at times, months—are like spring. Light thunder showers occur in the summer months, leaving a delightful, cool, and refreshing atmosphere.

In a recent report (1891) the State board of trade says:

> Land in Nevada that can be reached by water is certain to produce a good crop. Whatever grows here grows to the limit of quality. There is no rust on the straw nor weevil in the wheat. Apples and potatoes grow to perfection, while grapes, plums, pears, and all kinds of small fruits do as well here as anywhere.
>
> At New Orleans and other great fairs, wheat from a Nevada ranch and potatoes from a Carson River farm were awarded a first premium, and a dozen varieties of apples were awarded prizes. Nevada honey has taken the first prize at the California and Ohio State fairs, at the Mechanics' fair in San Francisco, and everywhere it has ever been shown. Tobacco and cabbages from Glendale also won premiums at New Orleans. Wherever there has been careful cultivation there has been successful farming. Last year, from 40 acres of ground which had been sagebrush land there was cleared $3,750, and nothing was planted but wheat, potatoes, and hay. With water for irrigating, the ground keeps on raising hay all summer and never fails to raise three crops and pasture for fall feed. Last year Mr. George Alt, of Glendale, put 15 acres of his ranch in vegetables. He raised off half of it 130 tons of potatoes, which sold for 1¾ cents per pound readily. On one-half an acre he got $700 worth of celery. One acre in cauliflower paid $1,000, and those who used it said it was as good as the best they ever saw. He sold 40 tons of cabbage at 1¼ cents per pound, from 1½ acres, besides other things, such as turnips, beets, etc., that the land produced. Mr. Alt says he knows, by the orders he had, that he could have sold a thousand tons of produce if he had had it. A close average of the yield of alfalfa for several years past would be 4 tons to the acre, worth from $4 to $7 per ton, according to accessibility to market; of potatoes 8 tons, worth $20 a ton; of wheat 20 bushels, worth $1.05 per bushel; of barley 35 bushels, worth 85 cents per bushel; of oats 50 bushels to the acre at 60 cents per bushel.

The governor, surveyor-general, and secretary of state, and other well-informed citizens of Nevada state that a great change has taken place in the sentiment of the people of that State as to irrigation during the past two years. The district or storage law is somewhat imperfect but very simple in its provisions. All that is required is to get a petition signed by two-thirds of the resident taxpayers, and to have the lines of the district marked. It is practically based on the California laws, and the districts formed will maintain a municipal organization. The people elect the commissioners by ballot, who decide what type of works shall be erected, while the electors reserve the power to vote bonds. The officers elected devise the plans for the control. Rates are levied upon the users of the water to pay the bonds and interest. The State legislature was necessarily unable to consider the question of taxing the users of the water on the public lands; and a bill was therefore introduced in the United States Congress, which it is to be hoped will become a law, to allow the settlers on public lands to be held liable for water taxes in irrigation districts. This would, according to the State officers, wonderfully improve the situation in Nevada. If it were law to-day there would be no difficulty in organizing the districts, because the organization of the latter would bring settlers. There is little agricultural land held in Nevada under the homestead law, but the lands they are now seeking to irrigate are held by private individuals under purchase from the State.

The Humboldt Valley has the largest area of land capable of irrigation. The Truckee and Carson rivers are of course the most easily available streams, and possibly the Walker. The Carson system is the most available because there is always water enough in the river to irrigate all the cultivatable area. There are about 751,000 acres that can be irrigated in the Carson Valley, and about 90,000 in the Truckee. There are already some considerable areas reclaimed in both valleys, with high cultivation at some points. In the Carson Valley there are two reservoir sites owned by Mr. Newlands, who is willing to turn them over to the State or the irrigation districts. These two are in Douglas County; there are two or three others in Washoe County, one in Churchill County, and one in Lyon County.

On the Carson is, first, the proposed Long Valley dam; next, the middle reservoir and lower reservoirs. It is also proposed to irrigate from Tahoe and Donner lakes. At the headwaters of the Little Humboldt there are some fine sites. The area fit for irrigation in the Truckee would be readily made available upon the organization of an irrigation district. Since the visit to Carson by the special agent this has been done. An organization has been authorized and the State Board of Trade has appointed a member to supervise the proceedings. The pending proposition was to embrace as many towns as possible in order to get the largest amount of taxable property in the district, so as to make the bonds more marketable. Mr. Newlands has proposed that the principal part of the State public lands be appropriated for the benefit of the districts. These are selected from the Government lands donated under special act in favor of Nevada. There is no considerable area of other public lands that are now available for irrigation districts except in the neighborhood of Wadsworth. The Humboldt basin is divided into several districts. There are sixty-three basins on the Truckee, Carson, and Humboldt, and in northern Nevada on the Owyhee River and its tributaries there are many more. It is perfectly feasible to reclaim all the arable lands on the Owyhee. In the southern and central portions of the State there is no great amount of water outside the Colorado River, but there are numerous small streams whose flow can be conserved; besides which there are many springs and a number of standing bodies of water, such as that in the Smoky Hill Valley.

No bonds have as yet been authorized or offered. The amendment of the constitution has been advocated so as to allow the school funds to be used as a guaranty of interest on the bonds. That school fund now amounts to $1,100,000. This proposition, said the governor, should be adopted for the reason that if the State is worthless what is the use of an idle school fund, and if these securities are worth anything why not loan on our own funds. If it is undertaken to invest this fund in the bonds of other States it is found that the rate of interest is very low, and nobody desires to borrow very largely, while the districts present an opportunity of enterprise considered perfectly safe, and they are willing to pay large interest. It is greatly to be wished that the power existed to invest this school fund in the irrigation districts.

Pastoral lands in the State are owned by a few parties in large tracts, they having got possession of it through indirect conveyances from the State.

In writing of crops for irrigation in Nevada there are a great many things to be considered—market, transportation, etc., all cut a large figure. Grain and potatoes can be produced better than is possible anywhere else, and they can be raised with a limited amount of water. All

Alfalfa Fields from the Sage Bush by Irrigation, Wadsworth, Nevada.

the root crops, cabbage, onions, etc., can be raised in abundant quantities. Nevada has early and late frosts, which are against it in fruit, but does not affect grain or root crops. In the southern part of the State cotton can be raised, also tobacco, sugar; in fact, Nye County produces practically the same crops as San Bernardino County, Cal. The temperature is even warmer than in San Bernardino.

The development of these crops by irrigation would greatly stimulate mining interests, and at the same time cheapen the necessities of the miners. It would at once create large products and a home market. This fact seems to be overlooked by almost everybody. They say, What is the use of raising grain when there is no market? In Nevada irrigation would create its own market by the mining development that must follow irrigation, in that way creating the very best of market.

The State surveyor-general discusses the subject of interstate waters in this wise:

> As to water that rises in one State and flows into one or many other States—it is my opinion that under present law it will almost be impossible to prevent collision between the States. It would be a clean cut fight between them, and to a certain extent would be the same as an international problem. The United States is the only party who can effect a just division of the waters, both national and international, between the different irrigation interests. It is the history of all irrigation litigation that the man highest up the stream has the best chance to use the water.

R. L. Fulton, of Reno, Nev., secretary of the State Board of Trade, one of the best informed as well as conservative citizens of that State, reports to the office of the irrigation inquiry in relation to the organization of an irrigation district in the Truckee Valley, as follows:

> The proposed Truckee River district is to extend from the State line between California and Nevada to the east end of the valley, and will embrace, of taxable property, $4,000,000. The present purpose is to issue bonds sufficient to secure the ownership, in the district, of such of the storage sites in the Sierra Nevadas as can now be obtained, but not to immediately make use of them. The sentiment prevails that the ownership should be secured now rather than to leave it to a time when their value may be enhanced by the pressure of population and the needs of the people. On the west, at a high altitude, there is one of the great snowfalls of the world, and on the east stretches a large area of very productive land. To bring these two together is the problem with which western Nevada has to deal. Fortunately, many places in the high Sierras are to be found quite well adapted to the storage of water.
>
> First, we have Lake Tahoe, an inland sea, lying at an altitude of over 6,200 feet, with a surface of 190 square miles. From this flows the Truckee River, through an outlet, where a dam could be constructed for a few hundred dollars, by which all the water can be stored that will ever be required. Under present arrangements Lake Tahoe is used by a company engaged in lumbering; the stored water made servant to them first, afterwards coming down to the farmers in an incidental way. The district can not obtain control of this at present, but probably will at some future day.
>
> Second in importance to this is Donner Lake, which lies in a depression of about 6,000 feet altitude, with a water-shed capable of filling it to a height of 20 feet every spring. It is 3 miles long and half a mile wide, and the outlet has been lowered 4 feet; so when filled the reservoir represents a depth of 24 feet of water, capable of flowing a stream equal to 10,000 miner's inches. With these there will be no danger of a drought on all the land at present under cultivation in the Truckee meadows. It is one of the sites which is open to purchase, and will be covered by the operations of the district when put into practice.
>
> Independence and Webber lakes are valuable storage sites used at present by lumber companies in their operations, but not embraced in the present plan of the Truckee district. In addition to these lakes there are a number of grassy flats now used as mountain dairies, from a few hundred to a few thousand acres in extent. Most of them have narrow outlets, through which living streams of water run. The most important of these are Sardine Valley, Henness Pass Valley, and Wheeler Valley. Water can be stored in all these to great advantage, and the district will undoubtedly desire to control them and hold them for future use.
>
> These future reservoirs, having a dam already constructed to a height of 12 feet, and a canal to a depth of 4 feet, can be secured by the district at an outlay of less than $70,000. It is not proposed to build canals to carry water to apply directly to

the land. This work, the people think, can be safely entrusted to private enterprise. The storage is held to be a proper public charge, as it will add to development. The district bonds will draw 6 per cent interest, and will be based upon the entire taxable property in the district, which will aggregate up to nearly $4,000,000.

On the Carson River a district embracing the whole basin is being organized, with a taxable property of $5,000,000. The facilities there are not so great as on the Truckee, but after the water is stored it will prove far more useful. Streams therein lie more nearly on a level with the surrounding country, so that long and expensive canals are not necessary. The land is very rich and stretches away in level valleys free from rock and alkali. Many hundreds of thousands of acres could be reclaimed at a nominal cost. A series of valleys extend from one end of the river to the other, and the water will be used over and over again. The Carson River has half a dozen mills where hundreds of stamps are engaged in crushing ores from the Comstock mines. Upon the supply of water in the Carson, therefore, depends the prosperity of Virginia City, Gold Hill, and Silver City. When the water is too low to turn the wheels the production of ore must cease and large numbers of men lie idle until the streams rise again. This can be obviated by the construction of a dam at Long Valley, where the water will be used first on a rich and fertile region lying in Douglas County, Nev. As it winds back into the stream it will maintain a regular supply to go through the mill wheel, after which it can be used in Lyon and Churchill counties for crops. Near the town of Carson another reservoir site can be made use of, and still below one in Churchill County is available; but it is thought that the Long Valley reservoir will be the only one needed until there is a larger increase in the population of western Nevada. The district will probably be bonded for $200,000 at first, which will secure the ownership of most of the land with these reservoir sites and construct the Long Valley dam. The interest on this will be about $12,000 a year, making a tax of more than 2½ mills on the dollar; so that a man paying on $10,000 taxable property would not have to bear an increase of more than $25 a year. This will be nothing in comparison with the benefits that he would receive.

On the Walker River there is abundant land and ample facilities for storage, which must be in demand in the near future.

The Humboldt River furnishes one of the greatest opportunities in America for irrigation enterprise. It is 300 miles in length, running through rich lands, and with its tributaries offering a hundred sites for reservoirs. Districts are talked of, and will, no doubt, be formed soon.

At a State irrigation convention held in Carson, statements of interest relative to the irrigation work and possibilities of Nevada were made, from which extracts may properly be given. Hon. Wm. M. Stewart said:

The limit of agriculture in this State will soon be reached unless the water attainable for that purpose can be stored, economized, and equitably distributed. There must be unity of action in the storage and distribution of water. Private ownership of water rights among a large number of persons is wasteful and expensive. Many small ditches lead to a great waste by evaporation and seepage, and make large annual expenditures necessary to keep them in repair. No individual can afford to construct expensive storage reservoirs for the benefit of the public, and what is everybody's business is generally neglected by all.

The difficulty of determining the respective rights of numerous claimants to a stream where questions of priority of right and the extent of the appropriation is involved is very great. A person desiring to irrigate land may come to the conclusion that there is ample surplus water unclaimed in a stream for his purposes, but when he has constructed a ditch he invariably finds himself in dispute or litigation as soon as the stream runs low or is decreased in volume by drought. If an irrigator attempts to enlarge the supply of water by storage he immediately finds himself in dispute with prior water claimants on the stream as to whether the water flowing down to his ditch is the natural flow or an addition to such natural flow occasioned by storage. Litigation naturally follows. The result is that at least nine-tenths of the water runs to waste which might be utilized to irrigate. I know of no instance where the water for irrigation has been well economized where there were numerous claimants to the water acting independently of each other.

The most satisfactory plan ever adopted, where there is a community of farmers to be supplied from a common source, is the formation of a municipal corporation to own the water and distribute the same among the irrigators.

Mr. Stewart further stated the difference between the California district law and that of Nevada, as follows:

The Wright law provides for the purchase or condemnation of all water rights and other property necessary for the use of the district. Our law provides for the purchase of all property necessary for the district, including water rights, and the condemnation of rights of way and reservoir sites, except existing water rights. As the law now stands, the question is whether immediate action shall be taken looking to economy in the use of water and the extension of agriculture in this State, or whether the whole subject shall be indefinitely postponed.

Irrigation districts are not new. They exist in almost every country where irrigation is practiced, and must exist if the water is to be economized and the largest possible extent of the available land utilized by irrigation. The four principal rivers of this State furnish ample water to irrigate sufficient land to support a population of from half a million to a million of inhabitants. Take the Truckee River as an example. Would it be an unreasonable estimate to say that sufficient water could be stored for use when needed to irrigate half a million of acres of land, which is now the amount irrigated in all Utah? The Truckee Valley and the valleys immediately north, which are equal in fertility to the Truckee Valley itself, comprise about 150,000 acres. By extending the district to include the region about and beyond Wadsworth within the flow of the waters of the Truckee, it would take in a very large area of land susceptible of irrigation. With 150,000 acres of land, all to be irrigated and cultivated, and the town of Reno as a basis for taxation, would there be any difficulty in negotiating long-time bonds at 5 per cent per annum interest to the extent of from one to two millions of dollars? Two millions would involve the payment of $100,000 per annum in interest at that rate.

What could be accomplished with that amount of money, and how could the rights necessary for the formation of the district be acquired? There is but one way to accomplish this desirable end under existing law. If all the owners of water rights on the river would fix a price upon such rights, at which they would sell them to the district and receive their water from high-line canals free of charge, except the necessary taxation to pay interest on the bonds and the cost of repairs of the water works, the success of the enterprise would be assured. There could be no doubt that the necessary rights to give the district the use of the lakes as reservoirs could be acquired by purchase as fast as needed, and that the landholders would fix a maximum price upon their lands, with easy conditions of payment, so that the entire district could be speedily placed in the hands and ownership of actual settlers. The owners of water rights on the Truckee could safely enter into such an arrangement; because if only 150,000 acres of arable land were at first included in the district, there would be ample water for all, and no farmer need have the slightest apprehension of a deficient supply. After it was ascertained by actual experiment that more land could be irrigated, the district could be extended and more taxpayers included.

Mr. Stewart then proposed the appointment of a committee of water-right owners, with the view of consulting other such owners and arranging a basis of sale of the same to the proposed districts, so that all may thereafter—

Take water in common with their neighbors, to be distributed by a municipal corporation. If that is practicable, you do not want any law of condemnation. You do not want to enforce it either, and it will be a voluntary act. If the persons owning the water rights will sell them for a reasonable sum, then the public can maintain and utilize them and distribute the water. The public must have them, but you can not take them away. It is a right they have acquired and it is recognized by law. The water will be under one management and will not be wasted. Litigation would never stop as long as individuals owned the water rights, because it is so necessary to know how much water they are entitled to take. If you store the water, there would be constant litigation to know how much water you are entitled to take resulting from your storage and how much resulting from the natural flow. To make this a success the water must belong to the public. There has never been a successful operation, where the greatest possible amount of land was cultivated, without the water belonging to the public. They found this necessary in California, and you will find it necessary here. You can not afford to have the water wasted in numerous ditches. You want to have it put upon the greatest possible amount of land.

Mr. Francis G. Newlands, in the course of a lengthy address, said:

The Humboldt River spreads almost from the eastern boundary of the State to the western, running from east to west, its waters falling into Humboldt Lake, called the Sink of the Humboldt—wrongly so called, because of the popular idea that once prevailed that the waters which flowed from the Humboldt into this lake sank into the bowels of the earth. As a matter of fact, they are drunk up by the sun.

The Humboldt flows with a full current until the middle of June or July. Farmers, however, hesitate to extend the irrigable area, because they are assured by experience that in June or July the flow of the river will be scanty and that their crops will not come to maturity, particularly the second and third crops of alfalfa. Hence irrigation on that river is limited.

Now, what have we to do? Simply to store and keep the water which comes down into Humboldt Lake at the various forks of the river—North Fork, Boulder Creek, Little Humboldt, and other sources of the Humboldt, and perhaps in reservoirs along the line of the river itself, where sites have been surveyed—to keep the surplus water there until it is required in June and July, and then let it down the river to be taken out by the irrigators. If efficient measures are adopted for the storage of the water in the storage sites that have already been ascertained, the Humboldt River is capable of reclaiming at least 500,000 acres, and probably even 1,000,000 acres.

A former United States surveyor-general, C. W. Irish, C. E., addressed a letter to the State convention, from which the following excerpts are made:

In round numbers, the surface of the State can be divided into 50,000 square miles of mountains and mountainous lands, 41,000 square miles of naked deserts and water surface combined, and 21,000 square miles of agricultural lands. Of the last, about 400,000 acres will be found in the foothills and cañons of the mountain ranges, 780,000 acres within easy reach of the water needed for its cultivation, and the remainder, 11,220,000 acres, so situated, or at so great distances from the water needed for its cultivation, as to call for capital aggregated in the hands of incorporated companies for its improvement. * * *

I very much doubt if the State has now 70,000 acres under the plow. It may have more than this quantity of land said to be cultivated, but a large share of it is simply watered to cause a larger growth of the natural grasses found growing upon it. We have an abundant water supply, which I am convinced is fully sufficient to put every acre of our now dry and useless agricultural lands under improvement. * * *

We should foster three classes of wealth-producers—farmers, stock-raisers, and miners—with the accompanying trades and callings needful to the wants of these three leading classes. We must do this, for the reason that our State presents in an abundance the natural resources upon which the classes stated thrive, and, in my opinion, it will paralyze our efforts to prosper the State if we ignore any one of the three classes named.

The agricultural lands should be placed in suitable quantities in the hands of only those who will occupy and improve them, and the water, justly subdivided, should be made an appurtenance of the land it vivifies. The mineral lands should be reserved for the discovery by and use of the miner, who will occupy and develop the metal-bearing veins.

The timber should be placed at the disposal of the miner and farmer, in quantities suitable to their needs, and the mountain ranges should be subdivided by tracing across them the township lines, but not subdividing the townships, setting the same number of corners for the marking of the interior lines of each township as are used to mark out a section, thus rendering it an easy matter to subdivide such surveyed townships. The mountain lands so surveyed should then be sold or leased (with proper reservation of water rights and storage of it in favor of the adjacent farming lands, and also of the minerals and timber which they contain or produce) to those who will take them and properly use them for stock raising or grazing purposes. * * *

It will cost not less than five and a half millions of dollars to survey the mountain lands of Nevada under the system as now practiced by the United States, while by the plan I have proposed it will only cost about three-quarters of a million of dollars.

The cost per township by my plan of surveys, and all other expenses attendant, would be about $650, and such township should be sold to actual users in wholes, halves, and quarters for $1,000 per township.

The sale of all classes of lands I have named to be made only to actual and immediate users, with no alienation of title by the purchaser, until complete improvement of the land sold to him, saving and excepting the timber and grazing lands, which should be required to be put to immediate use. The price of all the lands in Nevada to those who will take and improve them should be reduced much below what it is now. It costs the United States only from 2 to 5 cents an acre to acquire, survey, and sell the lands which have cost the purchaser $1.25 an acre.

I am sure that 780,000 acres of Nevada's lands can be brought under cultivation through individual effort alone at a cost not to exceed that which improved the wild lands of the Mississippi Valley, which was, on an average, $5.65 per acre for fencing, breaking up the sod, planting, and building to fit the claim for an abiding place.

The remainder of Nevada's lands can only, in my opinion, be brought under cultivation through the united work of the organized colonies, or by the aid of capital in the hands of incorporated companies.

The climate and soil of Nevada can produce all of the crops and fruits raised in the United States from Southern California around through Texas and the Southern States north of the Red River of Dakota.

Bulletin 163, United States Census Office (F. H. Newell, special agent), gives the following data as the enumerators' figures for the "census year ending May 31, 1890."

Number of farms		1,341
Number of farms irrigated		1,167
Average size of farms irrigated	acres	192
Average annual value of products	per acre	$12.92
Irrigated area (total) in acres		224,403

[NOTE.—The area in crops other than forage is estimated at about one-tenth of the whole, or 22,440 acres. It is also estimated that there were 280,000 acres irrigated for pasturage purposes.]

According to these figures, Nevada, with a population of 45,761 (see census returns 1890), would have had of crops other than forage over four-fifths of an acre per capita. With forage crops the irrigable acres would have been within a small fraction of 5 acres for each individual in actual cultivation, while, adding the "alleged" pasturage irrigation, the amount per head would have been over 11 acres.

The following table of grain and other cultivated areas is made from the sworn returns of the several county assessors for the year 1890, as given in the State Surveyor-General's Report for 1889 and 1890:

	Acres.
Churchill	1,018
Douglass	3,474
Elcho	6,961
Esmeralda	232
Eureka	1,427
Humboldt	5,012
Lander	3,048
Lincoln	2,250
Lyon	2,265
Nye	1,574
Ormsby	740
Washoe	3,074
White Pine	1,280
Total	32,355
Orchards (estimated)	5,012
Vines and small fruits (estimated)	9,500
Total cultivated, other than grasses	46,867

Separating all the crops given by the assessors from the hay crop in acres and tons, the following table is the result:

Counties.	Acres inclosed.	Acres cultivated.	Acres in hay.
Churchill	44,225	12,136	8,727
Douglass	30,000	20,000	12,000
Elcho	231,600	54,361	47,400
Esmeralda	6,000	4,000	2,500
Eureka	142,125	19,540	18,000
Humboldt	200,000	5,000	5,000
Lander	60,643	4,500	6,000
Lincoln	11,046	3,831	3,703
Lyon	34,000	8,000	12,480
Nye	16,035	10,132	932
Ormsby	5,016	2,019	200
Story	550	550	800
Washoe	45,637	8,810	18,620
White Pine	15,000	10,000	7,000
Total	641,899	162,879	143,362

The assessor's figures will necessarily prove to be the more correct.

Some explanation is necessary for a clearer understanding of these figures than would be given by a study without knowledge of conditions. In the first place the county assessment returns will give a crop return (other than grass or forage) of over one-third more than the bulletin figures allow. That makes no provision for the orchard, vine, and fruit area. The assessors give the number of trees, vines, etc., and allowing the usual space for each, the acreage is readily obtained. Altogether the total is nearly double the bulletin figures in cultivation other than for forage crops. In the next place the same authority gives as cultivated in all crops a total of 61,585 acres less than the census—very nearly one-third of the alleged area of 224,403. Again, the distinction made in crops is inadmissible in a fair understanding of the process and growth of reclamation from aridity by means of irrigation. Forage crops like alfalfa, timothy, clover, or other grasses, which are cured into hay and sold upon the markets, direct or as cattle, is as much a product of irrigation cultivation as oranges, sugar beets, grain, or any other special product. Area irrigated without planting or working, and simply for pasturage purposes, may be left out of all estimates.

ANSWERS FROM CORRESPONDENTS.

The following data have been compiled from answers received to circulars sent by this office:

LANDER COUNTY.

Battle Mountain (post-office), George W. Crune (September, 1891):

No irrigation systems in neighborhood and little land cultivated; water supply, Humboldt River and other mountain streams fed by the melted snows. Supply copious in spring, but scarce later; storage facilities very much needed; Government aid suggested; has a garden irrigated by an artesian well; water from small streams utilized in spring by settlers by very small ditches; small parcels of land near the mountains thus irrigated. About 25 miles above him on the river three or four dams have been built and ditches taken out, but settlers below have taken the matter into the courts.

WHITE PINE COUNTY.

Cleveland (post-office), A. C. Cleveland (September, 1891):

Neighborhood water supply, mountain streams and springs; capacity about 5,000 inches.
Irrigation works, about 13 miles of ditches of various sizes; no reservoirs or other works of much consequence.
Cost per mile of ditches, about $150 for larger ones.
Average cost per acre for preparing land for cultivation under irrigation, $5.
Average cost per acre for annual maintenance and repairs, about 30 cents.
Area in neighborhood covered by ditches, 4,200 acres (in grass and crops).
Products: Alfalfa, wheat, oats, barley, potatoes, etc.
Average yield per acre, about 2,000 pounds (not less).

CHURCHILL COUNTY.

Stillwater (post-office), Charles Kaiser (September, 1891):

Main water supply: Carson River, fed by snows of the Sierras (river runs for 75 miles through county); about 120 miles of individual ditches; no reservoirs; cost of ditches per mile, about $50; cost of water per acre per annum, about $1.50 (including maintenance and repairs).
Average cost per acre for preparing land for cultivation under irrigation, $10; for grazing, $4.
Area under irrigation at present, about 40,000 acres (water sufficient, with proper storage, to irrigate 150,000 acres).
Area covered by his own system, about 10,000 acres.
Chief products: Wheat, barley, oats, alfalfa, etc., and potatoes.
Average yield per acre: Wheat and barley, 1 ton; alfalfa, 4 tons (two cuttings); wild hay, 1½ tons.

St. Clair (post-office), Lem Allen (September, 1891):

Water supply: Carson River, water scarce in August.

Irrigation works: Three ditches; average length, 3 miles; 6 feet on bottom, 8 feet on top; capacity, about 500 inches each; 3 dams, 4 feet high, from 100 to 140 feet long; 3 head gates; no reservoirs.
Cost per mile of ditches, $60; cost of dams, etc., $200.
Average cost per acre for works, ditches, etc., about $1.50.
Average cost per acre for preparing land for cultivation under irrigation from $5 to $10; for grazing, about 50 cents.
Average cost per acre for maintenance and repairs per annum, about 50 cents
Cost of water supply to user per acre, $1.50 per season ; no annual rental
Area under ditch, 2,800 acres; under cultivation, 1,200 acres.
Chief products: Barley, wheat, oats, alfalfa, potatoes, and fruit.
Average value of crop per acre, from $8 to $14.

OREGON.

The entire State lies between the forty-second and forty-sixth parallels of north latitude, and between 116° 40′ and 124° 45′ of longitude west from Greenwich; from north to south the distance is 275 miles, and from east to west nearly 350 miles. It contains 95,274 square miles, and in all 60,976,000 acres of land. The northern boundary line, for two-thirds of its length, is made by the Columbia River; the western boundary line by the Pacific Ocean, and the eastern by the State of Idaho. That portion of the State which may be classified as arid and semiarid lies east of the Cascade Range, a continuation of the Sierra Nevada, which bisects the State from north to south, leaving the western slope and sea plane to occupy one-third thereof. The climate of that one-third is naturally humid and almost as much so as that of the British Isles. Crops, grass, and trees, with the exception of the mountain timber, bear a strong resemblance to the verdant fields of England. East of the Cascades the territory is divided into fourteen counties, the majority of which are very large. The northern portion may be considered as semi-humid in character, being watered by large streams, the Columbia and its tributaries, the Des Chutes, John Days, and Umatilla rivers. The Snake River, turning northward near Boise, Idaho, forms for more than half the State the eastern boundary. The highest ranges of the Idaho panhandle region, with the Blue Mountains in Oregon, make the northeastern section quite a broken country, whose foothills, however, are favorable for the cultivation of fruit. This region will probably develop a considerable supply of underground water both drift and artesian in character.

The southeastern and central portions of eastern Oregon is composed chiefly of moderately elevated plains, admirably adapted at present to pastoral purposes. The western portion of this section is a broken mountainous country, quite arid in character, with a few streams and some mountain lakes, filled by spurs of the Cascade Range, and having a rugged drainage area. The Des Chutes River, running, with its forks, north, is a deep, precipitous stream without much valley land, and the Klamath, in the extreme southwestern section of eastern Oregon, embrace with the Crooked River running east and west the principal water courses of the eastern Cascade region. Malheur and Harney lakes, practically one body of water, though named differently, form the central drainage basin of Harney County. Lake County, farther to the southwest, has a number of similar bodies of water; among them are Albert, Summer, and Warner lakes, in the center; Silver and Goose lakes, to the north and south. They are to a large extent shallow in depth, fed by the broken spurs of the Sierra and Cascade ranges, and considerably alkalized. Klamath, Lake, Harney, Crook, and Grant counties, with a considerable portion of Baker and Malheur counties, form the more arid region of eastern Oregon. Upper and Lower Klamath and Klamath Marsh, in the county of that name, form large bodies of water admirably adapted for storage purposes. The northern portion of Lake County, as well as a considerable part of southwestern

Harney and the southern and western portions of Malheur County, comprise a series of high table-lands, without water, and having a scant supply of grass.

The principal irrigation works now in existence in Oregon are found in Klamath, Baker, Union, and Umatilla counties. Mr. William H. Hall, formerly State engineer of California and ex supervising engineer of the United States Irrigation Survey, has been engaged during the past year as consulting engineer for large irrigation projects. In addition to a small number of works and the acreage they are now prepared to serve, there are, according to Mr. Hall, six large irrigation enterprises under way in eastern Oregon. There are ten or twelve others projected, considered by him to be entirely feasible. The Northern Pacific Railroad Company, the owner of an enormous area of land, a considerable portion of which must be irrigated in order to become valuable, has taken great interest and will sustain some of the projects of which Mr. Hall has been speaking. Along the Snake Valley, upon the Oregon side of the upper part of Malheur and the eastern part of Baker counties, some irrigation is in progress by means of water lifted from the river with pumping machinery. Considerable success has attended these efforts, and it is quite certain that for surface irrigation there is no more economical process than that of lifting from large streams like the Snake and Columbia rivers bodies of water sufficient to fertilize their bench lands. The irrigation engineers of India are strongly in favor, as a matter of economy, of the use of water by the lifting process.

The cattle and sheep raising interests of eastern Oregon, as well as that of mining, remain as yet indifferent to the progress of irrigation. The same apathy prevails in a large degree as that which twenty years ago characterized the few people residing in the San Joaquin Valley. The land for grazing purposes is scarcely worth the Government price; with irrigation it will unquestionably be worth from $40 to $60 per acre. As soon as the water is brought into juxtaposition with the land cultivation begins. Each one of the projects mentioned by Engineer Hall will, according to his estimate, reclaim from 50,000 to 100,000 acres of land, or, in all, 1,250,000 acres. A moderate statement from other sources of the reclaimable land in eastern Oregon places the total at 3,000,000, considerably less, in the judgment of others whose opinions are of value, than the facts warrant. Mr. Hall's estimate for works is of a costly character, involving an outlay of about $12,000,000. Information from the State Chamber of Commerce at Portland estimates that there are approximately 3,000,000 acres of land within the State, located in Wasco, Grant, Umatilla, Baker, and Malheur counties, that could be easily irrigated from the waters of the Snake and Umatilla rivers, Harney Lake, and numerous creeks found there. Mr. S. B. Willey writes:

> I can learn of nothing in the way of any estimate ever having been made of the cost of ditches for irrigating land in any of these sections, but should consider that the cost would not be very great, owing to the large volume of water that could be tapped and the fact that the natural fall of the streams is in the direction of the land required to irrigate. Small patches of land in Umatilla County along the Columbia River which have been irrigated simply by means of hose show a luxuriant growth of grass, trees, and small fruits; peaches, grapes, etc., have grown very abundantly.

Through the Chamber of Commerce also, the following letter from C. E. Foster, C. E., of Baker City, Oregon, has been received:

> Irrigation in Eastern Oregon is progressive; although no comprehensive system for the reclamation of large areas has yet been matured, still individual farmers wherever practicable are extending their ditches to cover larger acreage and distribute water more economically, as their experience has proven that artificial irrigation doubles and trebles the quantity of their crops. As a rule in this vicinity every

farmer utilizes all the water available for irrigation purposes, and the chief trouble lies in the fact that the water supply is limited. As the country fills up with agriculturists the quantity of water for each individual grows less; hence irrigation is made a study by the farmer, to the end that he may so apply the water at his command as to realize the best possible results. It is a conservative estimate to state that 100 miles of ditches have been constructed in Union, Baker, Grant, and Malheur counties during the past year by individual farmers.

As additional evidence of the increasing interest taken in irrigation in eastern Oregon it may be stated that during the past season various companies have been organized for the purpose of constructing reservoirs on an extensive scale and to build canals of sufficient capacity to reclaim many thousand acres of desert lands. One of these companies has located a reservoir site on Powder River in Sumter Valley (Baker County), 20 miles southwesterly from Baker City. This reservoir will cover 1,400 acres of land with an average depth of 30 feet of water. Preliminary surveys of the main canal and distributing branches have been made and the engineers are now in the field. This system when completed will afford irrigation to a large portion of the Powder River Valley with the country immediately east thereof, and is intended to supply water sufficient to reclaim 75,000 acres. Another enterprise of similar nature, having for its object the irrigation of 5,000 acres in and adjacent to Eagle Valley in Union County, has been undertaken, and surveys for the canal are now being made. The water supply for this enterprise is to be furnished by Eagle Creek.

A movement is being made in Umatilla County to utilize the waters of the Umatilla River and reclaim a large tract of land situated near the base of the Blue Mountains. The canal for this purpose will have a carrying capacity of 25,000 inches.

The owners of the Eldorado Ditch, situated in the southern part of Baker and the northern part of Malheur counties, which was originally constructed for mining purposes at a cost of $400,000, have taken the initiative steps to use a portion of their water for irrigation. To this end lands have been bought and located and additional lines of ditch have been surveyed. This scheme will reclaim from 5,000 to 8,000 acres. The Malheur River has been dry at its mouth during the past season because of the various ditches tapping it. The principal ditches taking water from this river are the Nevada Company's ditch, 20 miles long, 2 by 8 feet; the Frohman ditch, 6 miles long, 2 by 6 feet; the McLaughlin ditch, 4 miles long, 2 by 3 feet; the Thompson ditch, 3 miles long, 2 by 4 feet, and the L. F. Company's ditches, one 3 miles and one 14 miles in length; capacity, 2,000 inches.

The Owyhee River has not been utilized to any considerable extent and possesses all the features necessary for an extensive plant for irrigation; large tracts of fine soil lie adjacent to the river and to Snake River, and 50,000 acres could be covered with a canal 25 miles in length.

Reservoirs for the storage of the surplus water of springtime must be constructed in this country before the agricultural capabilities of eastern Oregon are developed; as most of the streams have already been appropriated and the water supply is insufficient, it becomes a matter of necessity that such reservoirs be constructed.

Engineer Hall describes the Powder River Valley irrigation plan as designed to secure the irrigation of 90,000 acres of land. A dam 137 feet high is to be completed across the river, making a back-water storage over an area of 16,000 acres. At least 60,000 acres of the proposed land to be reclaimed is entirely worthless without some such water supply. A contract of $2 per acre as a water rate is being asked by the company engaged in this enterprise. Baker County has, adjacent to Baker City, one irrigation canal served by a storage reservoir, the cost of which is given at $60,000. In the Powder River Valley there are 10 artesian wells reported in operation, 4 of which supply Baker City with water for town and domestic purposes. No details are accessible as to their depth, strata, volume, or pressure. In Klamath County, the southwest section of eastern Oregon, irrigation works are reported, the main canals of which have a length of 32 miles. The cost of these works is stated at $32,000 and the acreage served at 30,000. The source of the water supply is the Upper Klamath Lake. It is estimated that the waters of the Upper and Lower Lakes, so named, can be utilized and so distributed as to serve 200,000 acres. The crops grown on the land irrigated are wheat, rye, oats and barley, alfalfa, potatoes, and timothy grass. During the past season 2,000,000 bushels of grain were raised, being over 60 bushels per acre. The selling value of irrigated land is from $15 to $20 per acre; nonirrigated, the Government price is $1.25.

Umatilla County reports that not less than 300,000 acres, now valuable only for pasturage, could be made to yield, with irrigation, excellent crops. This land, situated in the bench or mesa formations of the river valleys, has already been occupied, farmed, and abandoned, because of the insecurity arising from insufficient rainfall. The sources of water supply in Umatilla County, besides the Columbia River on its northwest border, are the Umatilla River, the Mackay, Burch, Butler, and other creeks. The Blue Range, running from north to south with an east and west trend, forms on the eastern edge of the county a natural water-gathering area, the effect of which is seen in the numerous bored wells that are to be found among the foothills and small valleys thereof. A company has been organized to utilize the Umatilla River supply. It is expected that at least 67,000 acres can be reclaimed thereby. No valuable site for a reservoir is found on the river, and therefore the flow only can be made available. The small streams are, however, all of them capable of being impounded in storage basins, so that the entire supply that now largely sinks into the ground can be, it is claimed, made useful. The area of irrigated land is quite small as yet, small patches along the river being only so served. There are many bored wells in the county, used generally for stock and domestic purposes. No trial of any extent has been made as to fruit. Wheat and other cereals average 25 bushels to the acre, and the yield can easily be doubled by means of irrigation.

Morrow County, with 161,908 arable acres, located to the west of Umatilla, is largely served as to water by means of its phreatic and subirrigation supplies. The irrigation practiced is quite limited, the supply being usually from small creeks. A large number of shallow wells have been bored or dug and the water is generally used for stock and domestic purposes. At Heppner, the county seat, an artesian well is being sunk. Its present depth is 650 feet, but as yet no flow has been obtained. Water was struck with a temperature of 65 degrees, very pure and apparently inexhaustible—evidently a drift or underflow supply that does not rise to the surface. It is proposed to sink a deeper well and, if possible, reach artesian waters.

The following paragraph is from a letter to the Department, sent by Hon. W. H. Bejers, United States surveyor-general of Oregon:

> There is a vast territory of bench lands along the Columbia River, from the Blue Mountains on the east to the Cascades on the west, that might be greatly benefited by irrigation. From the north boundary of Crook County to the south boundary of the State, are many valleys of fine soil; also high plateaus of good agricultural lands which are now only "desert" from the fact that they are not supplied with water. Much of the Crooked River and Ocho valleys are nearly worthless on account of the scarcity of water. The "Desert" between Crooked River and Silver Lake is only so named because no water is found in that region. The same might be said of all the county east and south to the State line. A vast amount of it may never be reclaimed, and yet there are many acres of fine lands, and if there were only enough water a crop could be secured. Around nearly all the lakes in southeastern Oregon are a great number of acres of good level lands, with fine soil, that need to be properly irrigated. Some of these lands are eaten up with alkalies, but about Clear, Summer, Goose, Klamath, Harney, and Warner lakes there are large bodies of good land. There is a small lake some 15 miles east of Warner, in the southeast part of the State that must have nearly two townships of fine land, all worthless now from a lack of irrigation. My idea is that these high lands would require artesian wells, while the low lands in most cases might be irrigated by the waters of the lake. The table lands between the Blue Mountains and the Columbia would also be a fine locality in which to experiment for artesian waters.

Wheat is the staple agricultural product of eastern Oregon. Its quality has made it famous in the grain markets. The yield averages from 25 to 30 bushels per acre, and often exceeds 40 bushels. In 1887 not less than 300,000 tons, or 10,000,000 bushels, were offered for sale. Of this total the country east of the Cascades yielded 200,000 tons. The amount has been largely increased since that date. Irrigation will easily double the products of the same area.

East of the Cascade Range the soil is of a dark loam of great depth, composed of alluvial deposits and decomposed lava overlying a clay subsoil, and rests upon a deep basaltic formation. This soil is peculiarly adapted to wheat-growing. All the mineral salts which are necessary to the perfect growth of the cereals are abundant, reproducing themselves constantly as the gradual processes of decomposition in this soil of volcanic origin proceed. The clods are easily broken by the plow, and the ground quickly crumbles on exposure to the atmosphere. In southeastern Oregon, notably in Malheur and Snake River valleys, the soils are much like those of the northeastern Oregon region, but there is less moisture. Except in a very small proportion of this region, irrigation is necessary to successful agriculture.

The climate east of the Cascades generally gives a temperature higher in summer and lower in winter than that west of the range. The winters, though short, are sometimes severe, and the summers are almost entirely arid. The average amount of rainfall throughout eastern Oregon will not exceed 15 inches per annum. The upper part of the State and the section of the valley of the Columbia River make a funnel by which the influence of the Japanese current is strongly felt, bringing in winter what is known as the "chinook" wind, which greatly modifies the temperature over the larger portion of the eastern section. The thermometer ordinarily indicates 90° as the highest summer temperature, and 10° above zero as the lowest for winter. In the highest valleys, among the mountains, the winters are also short and rather severe. Snow seldom falls before Christmas, and sometimes lies from four to six weeks, but usually disappears in a few days. In the northern and eastern counties spring begins in February with warm, pleasant weather, and lasts until the middle of May. The average temperature is 52°. Autumn weather, in October and November, is generally good; there are often frosts by night, but the days are usually warm and bright. The season is marked by showers, and also by thunderstorms in some localities. The mercury ranges between 55° and 70°. The annual rainfall does not average more than 20 inches, but south of Powder River it is not more than 15 inches, increasing gradually to the north. At Camps Watson and Grant, in the central plateau region, an average of 14 inches per annum is shown. Camp Harney, at a greater elevation, gives less than 9 inches. The Dalles, Wasco County, at 350 feet elevation, gives for a period of thirteen years an average of 21.06 inches; for the summer months, 2.10; for the winter, 13.56. Umatilla County, in the northeastern portion of the State, gives an annual mean of 9.81 inches; 1.66 for the summer months, and 4.78 for the winter ones. Fort Klamath, in the southwest, at an elevation of 4,200 feet, shows a mean annual temperature of 43.2°; for summer, of 57.2°; for winter, of 30.6°. Its precipitation gives a mean annual average of 21.60 inches; for summer, of 1.90; for winter, of 13.72. Lakeview, in the same section, at an elevation of 4,850 feet, gives a mean temperature of 47.1°; for summer, of 64.6°; for winter, of 33.5°. Its records show a precipitation of 18.98 inches annually; for summer, of 3.08; for winter, of 6.79. Linkville, at an elevation of 4,250 feet, presents a mean annual temperature of 48.5°; for summer, of 63.3°; for winter, of 35.3°. Rain and snow fall of 17.85 inches annually; for summer, a fall of 1.87;

for winter, one of 7.77 inches. The southwestern section, then, of eastern Oregon will give in temperature a mean of 45.9°; in precipitation a mean of 19.72 inches, and of elevation 4,525 feet.

La Grande, the county seat of Union County, in the northeastern portion of Oregon, has an elevation of 2,784 feet; its mean precipitation is 24.55; for summer it is 2.66 inches; for winter it is 15.81.

These figures, especially as to the summer and winter precipitation, place eastern Oregon as to climatology in direct relations with the arid region west of the western slopes of the Rocky Mountains, that is, from Utah to the Coast Range. East of the Rockies and within the irrigable valleys, basins, parks, and bench lands thereof, the annual precipitation, divided into three periods of four months each, will give the smallest precipitation for the months of January, February, March, April, and the largest during May, June, July and August. In the growing and ripening months west of the Rockies, the records show an almost exact reversion, the least precipitation being in the four growing months and the heaviest in the first four of the year. By precipitation is meant, of course, measured inches of water. The chief cause of this notable difference is found, in all probability, in the relative severity of the winter of each division. It is one that must be borne in mind when considering irrigation problems.

In volume 4 of the testimony taken by the Senate Special Committee on Irrigation, the following table gives, on the authority of J. W. Steele, the amount of land irrigated and under ditch within the boundaries of eastern Oregon:

Counties.	Acres irrigated.	Acres under ditch.
Baker	5, 000	10, 000
Crook	8, 000	8, 000
Gilliam	3, 000	5, 000
Grant	10, 000	10, 000
Harney	20, 000	20, 000
Klamath	5, 000	30, 000
Lake	5, 000	5, 000
Malheur	40, 000	60, 000
Morrow	6, 000	18, 500
Umatilla	5, 000	7, 000
Union	5, 000	8, 000
Wallowa	7, 000	10, 000
Total	109, 000	191, 500

This table bears the date of June 27, 1889, and was presented by Director Powell, of the U. S. Geological Survey. More recent investigation establishes the fact that not over 75,000 acres, instead of 191,500, were under ditch in the whole of eastern Oregon, and not over one-half of that acreage was cultivated. A reasonable estimate will increase the area cultivated to date to 45,000 acres, and that under ditch and valuable for irrigation at 100,000 acres. This is a liberal statement.

The Umatilla Valley during 1891 has been the seat of considerable activity. Six companies are operating therein, and disputes have arisen requiring suits to settle the question of priorities. These, however, are understood to be of a friendly character, for the purpose of enabling the larger corporation to settle all controversies, and so enable it to dispose of its bonds. Another suit for the same purpose will decide the constitutionality of recent irrigation legislation and will settle the rights of riparian owners. The humidity of western Oregon renders acceptable therein the English common law on water; in eastern Oregon, however, that of the public control for beneficial uses, as is the case in all arid regions, must control. Pumping for the irrigation of orchards is being extensively practiced along the Columbia River. In the Snake Valley, both in Idaho and eastern Oregon, the current wheels, as they are termed, which have long been in use for lifting water onto the placers for mining purposes, are now being utilized for raising water to be used in irrigation. They are large wooden wheels from 12 to 24 feet in diameter, along the flanges or wings of which are ranged wooden buckets, so hung as to dip and bring up the water to be emptied into a flume or conduit, by which it is conducted into distributing ditches, or in some cases into tanks or reservoirs. The wheels hang in a strong gallows frame, and are moved by the current. It is reported that 500 cubic feet per diem can be lifted with ease. At Baker City and in the valley of Tongue River, the use and extension of irrigation is steadily increasing; on McKay Creek, at Pendleton, the irrigation works are steadily progressing. They are of considerable magnitude. The construction of the reservoir requires comparatively little labor and expense, as three natural walls exist. When the dam is built a lake will be created 22 feet deep and covering an area of 170 acres, with a capacity of 900,000,000 gallons. There will be a supply of water easily sufficient, it is claimed, to irrigate 25,000 acres. The same active workers who direct Boise and Nampa system, in southwest Idaho, are interested in the Pendleton reclamation work. There is good reason to expect the finding in this section of a fair supply of artesian water and a moderate pressure.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers to circulars received by this office:

HARVEY COUNTY.

Burns (post-office), Mrs. M. E. Dalton (November 22, 1891):

Under cultivation, 160 acres; area "under ditch" in vicinity, 3,000 acres.
Water supply: Silvies River, fed by springs and mountain snows; valley 75 miles long, 50 miles wide; mostly sagebrush land, worthless without irrigation; water sufficient to irrigate all land in valley annually wasted; dam at cañon needed; works (in progress), dam 25 feet from bank to bank; depth of water, 6 feet; headgates and other gates being built, 10; ditches, 6 miles in length, 14 feet wide at top (sloping to bottom); depth, 2 feet.
Flumes (probable cost of), $100.
Cost of ditches per mile, $100.
Cost of maintenance and repairs, 15 cents per acre.
Annual cost of water, 33⅓ cents per acre.
Products: Hay and grain; product per acre, hay, 1½ tons; wheat per acre, 50 bushels; oats and barley, 75 bushels per acre.

KLAMATH COUNTY.

Linkville (post-office), G. W. Smith (October 17, 1891):

Water supply: Big Klamath and Little Klamath lakes (big lake, 37 miles long by 8 miles wide; little lake, 15 miles long by 6 miles wide).
Irrigation works: Two ditches (one from each lake), each about 12 miles long; ditch from big lake carries 1,000 inches water; ditch from little lake about 2,500 inches; one headgate for each ditch; several flumes.
Cost per mile of ditches: Big lake ditch, about $1,000.
Cost of water to user, $4 per inch; about same per acre.

Linkville (post-office), J. T. Henley, president Klamath Falls Irrigation Company:

Source of water supply: Big Klamath Lake, supplied by 3 or 4 small rivers; supply continuous and abundant; "outlet to lake is Link River, which carries about 100,000 inches at low tide."
Irrigation works: Ditch 16 miles in length; width, 12 feet at bottom, 16 feet at top; reservation projected.

Area under ditch, 100,000 acres; under cultivation, 1,200 to 1,500 acres; using water, cost of ditches, etc., per mile, about $1,250.
Average cost per acre for preparing land for cultivation under irrigation, about $7 (in vicinity of this ditch).
Average cost per acre for maintenance and repairs, per acre, about $1.50.
Cost of water supply to user, $4 per miner's inch per season.
Products: Wheat, rye, oats, barley, potatoes, and most hardy vegetables; also alfalfa, timothy, redtop, red clover, and all grasses.

UMATILLA COUNTY.

Pendleton (post-office), secretary Blue Mountain Irrigation and Improvement Company (September, 1891):

Source of water supply: McKay Creek (stream has flow of 45 cubic feet per second; drainage area, 135,000 acres, all wooded).
Irrigation works (construction commenced September 26, 1891): 58 miles ditches, 15 feet on bottom, 27 feet top (main ditch); one reservoir, area 170 acres; average depth, 22 feet on 50-foot level; dam 280 feet on bottom, 520 feet on top (length); five headgates (it is also proposed to supply city for domestic uses).
Cost per mile, ditches, $2,800 (estimated); cost of dam, $70,000 (estimated).
Annual rental cost of water per acre, $3.
Area under ditch, 30,000 acres.
Area under cultivation, 10,000 acres.

Pendleton (post-office), E. J. Horton, McKay Creek Irrigation Company (September 23, 1891):

Water supply: McKay Creek (a mountain stream with capacity of about 2,000 miner's inches).
Irrigation works: Six and one-fourth miles ditch, 5 feet at bottom, 8 feet at top; two dams 5 feet high, 60 feet long; two headgates; no reservoirs.
Cost per mile of works, $300; average cost per acre, $3.
Average cost per acre for preparing land for cultivation under irrigation, about $5; for annual maintenances and repairs, 25 cents.
Cost of water supply to user per acre, $1; annual rental, $3.
Area under ditch, 1,500 acres; under cultivation, none.
Products of neighborhood under irrigation: Wheat, corn, alfalfa, timothy, fruits, and vegetables of temperate climate.
Average yield per acre; Wheat, 50 bushels; corn, 60 bushels; alfalfa, 10 tons; timothy, 4 tons; beets or carrots, 60 tons.

WALLOWA COUNTY.

Wallowa (post-office), J. F. Johnson:

Source of water supply: Wallowa River, average width, about 75 feet; depth, 18 inches; has fall of 100 feet per mile; banks about 3 feet high.
Irrigation works: About 1 mile of ditch, 6 feet at top, 3 feet bottom; brush dams (no reservoirs).
Cost per mile of ditches, $50; cost of brush dam, $50, complete.
Average cost per acre of works, ditches, etc., 50 cents.
Cost per acre for annual maintenance and repairs, about 5 cents.
Area under ditch, 800 acres; under cultivation, 200 acres; 600 acres in grass, hay, timothy, redtop, clover, or native grasses; 200 acres in wheat, oats, and rye.
Yield of products per acre: Wheat, 30 bushels; oats, 50 bushels; rye, 2 tons; timothy, 2½ tons; redtop, 3 tons.

UTAH.

The chain of mountain ranges known as the Wasatch extend from about the center of the northern boundary to the extreme southwest corner, where they leave the Territory. Near the latitude of Salt Lake City the Uintah, a more lofty and rugged range than even the Wasatch, starts off about due east. From this range, again, in the latitude of Utah Lake, and 40 miles east thereof, the Coal Range extends in a line parallel with the Wasatch for about 160 miles, until near Panguitch Lake, where the broad rolling summits of the Coal Range merge into the more precipitous peaks of the Wasatch. The Uintah, the Coal Range, and the southwestern extension of the Wasatch wall, in that portion of Utah originally included in the Great Basin, form the series of mountains which make the central Utah divide and control the drainage areas of the Territory. North of the junction with the Coal Range, the Wasatch Range forms no part of the rim of the Great Basin, although its lofty peaks gather no small portion of the water needed to reclaim the Great Salt Basin.

The bulk of the population and cultivation in Utah is centered around Great Salt Lake, in the counties of Cache, Boxelder, Weber, Davis, Salt Lake, Utah, and Tooele, which form that portion of the basin at present extensively irrigated.

The Jordan (considering the Provo River as its head) Weber, and Bear rivers, are now the principal sources of irrigation. They rise near together in the Uintah Mountains, pierce the Wasatch Range at widely separated points, and empty into Great Salt Lake, contributing the majority of its visible inflow. But besides the drainage of these three rivers, from the Escalante Desert in the extreme south to the northern boundary every drop of water that falls on the high surrounding mountains drains through the salinas and desert plains toward the Great Salt Lake. The heavy precipitation upon the Coal Range and the Wasatches pours in torrents into the bowl of the Great Basin, quickly sinks into the deep wash soil and disappears from sight. As we approach the lowest depression, known as the Great Salt Lake Desert, all signs of water are lost. Therefore, dividing Utah into two great parts, it will be seen that the eastern and southeastern sections drain through the Rio Colorado system to the Gulf of California, while the western and northern portions have no apparent outlet. In the former, no matter how intricate the meanderings, the streams rising on the eastern flanks of the ranges named contribute a portion of their flow to the great Colorado River, while on the other side of the divide not a single stream carries its flood to the sea, and with four exceptions, viz, the Jordan, Weber, Bear, and Sevier rivers, none flow more than a few miles beyond the base of the mountains. The summits of the surrounding peaks are usually covered with snow and the water precipitated therefrom must find its final visible resting place in Great Salt Lake, the remnant of that vast geological lake, known as the Great Basin.

A very important factor in Utah irrigation would be a settlement of questions connected with the precipitation of the western flanks of the Wasatch Range. These valley lands are more accessible to market than the balance of Utah, and when we consider that one cubic foot of water per second or 646,520 gallons per day, flowing continuously during the irrigation season will irrigate an average of 100 acres of land, it becomes of the utmost value to comprehend the source of supply; and in this connection the experience and knowledge of H. L. A. Culmer, editor of the Salt Lake Journal of Commerce, is of material value:

> I believe our present water supply in Salt Lake Valley, and in similar tracts, could be doubled from sources that are now invisible—at least doubled, and certainly along the western flank of the Wasatch Mountains, and in many of their valleys I know that there is an abundance of water to be had, which if developed is sufficient to cultivate every acre. I want to say this, however, that seeing as years go by, that so much more is accomplished than was once thought possible, it is difficult to estimate the future possibilities. Such an estimate would sound Utopian. This statement only includes what may be done from water in sight and the known phreatic supply. I have not considered the limit of irrigation by storage of artesian and surface flowing water to have been reached; on the contrary I believe the desert portion of Utah will become more and more circumscribed, and, perhaps, some day be wiped out from these supplies as the principal source.
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> Speaking on the question of storage I may say that I am very familiar with the Wasatch Mountains, and I know that near the heads of all these cañons there are natural reservoirs. In the Wasatch Mountains, within 20 miles of Salt Lake City, nearly every cañon has at its head an Alpine lake varying in size from a few hundred yards to a mile and a half across. These have evidently been formed by glacial moraines damming up the cañon, making a stronger reservoir than human hands can construct, and larger too. Many of these are very deep, and their outlets are the initial points for the cañon streams. A great deal could be done by heightening these natural dams and thereby increasing the capacity of the natural reservoir. I believe they could be made to hold twice their present capacity. Any attempt to create reservoirs in the cañons other than at these points would be puny in comparison.
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> It must not be forgotten that at these points of natural storage the evaporation is at a minimum on account of the altitude. There are many others of these alpine lake sites which are now dry, having given way or been worn through at some points. A little work would make them as good reservoirs as those remaining.
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> My first statement as to the possibilities of reclamation of arid land was made without taking these natural reservoirs into account. Referring to the ultimate reclamation of the desert lands of Utah, I think it will be accomplished primarily by means of the development of water by artesian and driven wells, which will permit the cultivation of limited tracts whereon these wells are secured. Alfalfa and other deep-root crops will be planted at such points, and, in my opinion, will exert a capilary influence on the earth to a depth great enough to reach the water-bearing stratum. This vegetation will also shade the earth and perhaps have a local effect in preventing the drying of the soil, and effecting a change on the lower strata of the atmosphere. As an example of this effect I would refer to the western half of the Salt Lake Valley in the neighborhood of Salt Lake City, which a few years ago was considered worthless for agricultural purposes, because the first attempts at farming were extremely unsatisfactory and disappointing—the ground seemed to require so much moisture, and the crops literally burned up. Until recent years it was considered a desert country and it was not expected that it would ever be peopled. Now, that is what I would call the eastern flank of the Oquirrhs in the Salt Lake Valley. As land, however poor, in the immediate neighborhood of the city is higher priced, the people made extra struggles to secure a living from this arid district. They planted alfalfa in large tracts, and this not only redeemed the quality of the land, but seemed to have made the whole district more moist; and when water was found to be obtainable by means of driven wells, each of which would furnish sufficient water for the cultivation of a tract of 5 acres, the land became valuable, is now largely settled, and is looked upon as a productive region many miles in extent.
>
> Artesian wells in Salt Lake Valley were first used for irrigation about seven years ago, and since that time have increased the area of cultivation from 25 to 35 per cent. It is to be remembered, however, that in the large area of agricultural land in Utah, only a limited portion has yet tried to develop artesian water.
>
> In Emigration Cañon, within 4 miles of Temple Block, the city corporation took the cañon stream and flumed it for a short distance so as not to interfere with its flow by subsequent work. At the point flumed it was estimated that an underground

supply could be developed, and the city dug a trench about 100 feet long and 40 feet deep, projecting the sides with plank with open joints strongly braced. The trench was filled 30 feet deep, and this new supply is drawn off through a 12-inch iron pipe to the city at the rate of 1,250,000 gallons a day. Within 100 feet of this source another long open trench was dug which yields 1,000,000 gallons per day, and this supply is wholly supplementary to that which formerly made the cañon stream. This water is used for city purposes, but it seems to me a big hint to all agriculturists.

In Provo Valley and Krammer Valley I think the same amount of water supply can be obtained. I am also satisfied that every acre of land in the Duchesne Valley can be cultivated from a similar source, and all the arable lands from Strawberry Valley to Book Cliffs could be reclaimed, and the San Pete Valley, also. The Cache Valley, also, has enough of water. All the eastern side of Box Elder Valley, probably Rush Valley, and most likely Fowl Valley can be reclaimed. Sevier Valley is also capable of reclamation, although there nothing has been done.

A belt of extremely rich country, 25 to 75 miles wide, almost the entire length of the Territory, may get sufficient water from the western flank of the Wasatch Range, and can be reclaimed. Every acre that is not watered in the regions named I believe could be from the surface and underflow of the mountains. There are also many valleys in the middle and southeastern part of the Territory which are not sufficiently watered, but which could be with more or less work.

These statements are made on intimate knowledge of this Territory, gained from personal observation and conversation with hundreds of farmers from the regions named.

If you will take the Emigration Cañon work as a basis you will see that I am not overestimating the areas.

I feel now that it would be better to go for the underground supply. It is the quickest method. While there have been very few thoughtful attempts to develop the underground supplies, I know of some instances that have been very successful; but the point I would emphasize is that as a general proposition (and they always have exceptions), a cañon will yield a large supply of water all the year round; at the lowest stage the smallest will yield 1,000,000 gallons daily. Sometimes you will find a dry cañon and one right adjoining full of water. It seems that the water is diverted in some cases from the cañons. I know of many cañons that have within a few miles of the base copious springs, which flow a short distance and sink. They are evidently the natural outpouring of the water after it has gone underground at high altitudes. This underflow could, unquestionably, be tapped, and if reached at bed rock could be brought down to irrigate the bench lands which are very fertile. I am of course speaking of cañons of the Wasatch Range, which are unique in that they have no parallel range of foothills.

On the western flanks the precipitation that falls on the summits sinks into the earth as there are no rivers to carry off the waters of the rain and snow. The drainage therefore must be towards the cañon, as the water would naturally follow the mountain lines till it finds a place with more or less appearance of a channel. I think some of the driest cañons that abut on this valley have at their heads the greatest amount of snow, and are consequently drainage troughs of that vast amount of water. Take for instance the cañon next south of Little Cottonwood Cañon—little or no water goes over the surface and if any goes underground it is wasted, yet at the head of that cañon is an enormous snow basin. The snow lies there always to the depth of many feet; where the water goes to we do not know, but in all probability it follows down the course of the cañon. These cañons are filled with detritus into which the water, that you would naturally expect to flow on the surface, disappears. I feel sure that an inclined tunnel would be sure to find an immense amount of water in all the cañons. I feel satisfied that there is more water beneath the surface than above. About 17 miles south of Provo is one of these dry cañons, called Springville Cañon, very rocky, precipitous, and dry. It looks as if it should yield a copious stream. It is, however, dry while out in the valley is a stream that emerges right from the bank. In other words, through the underflow gravity a considerable stream makes its appearance. When the emerging flow soon becomes a stream, you feel that there is the point where the water line reaches an impervious stratum, and by it is forced to the surface. The same phenomenon is repeated a number of times along the base of the range. Right along in the mountains east of Utah Lake there is unquestionably an abundance of water of which I have already spoken. It also suggests itself to me that under the surface of both Utah Lake and Great Salt Lake, there emerge many heavy streams of fresh water. I do not think these lakes are by any means supplied by the water we see going into them.

Now, take the range here at Pleasant Grove, the mountain is very steep and high, with an almost perpendicular rift; there is no watershed, but a heavy stream comes down. The conditions seem to be reversed, but there is no doubt that this water comes from the other side of the range, miles away, right through the mountain. The line of the summit is just like a man's knuckles, and the summit is between 3,000 and 4,000 feet above the stream. Yet that water comes right through that mountain and out into the valley. Further south than Utah Lake, on the line of the Union Pacific Railway, in the Sevier Valley, in Midland County, in the neighborhood of Deseret, I believe that water can be developed here by the artesian process. But the further you get from the range the deeper you will have to go.

My experience is that no man can take it upon himself to say that there is any tract that can not be cultivated. We have done so much in reclaiming the desert that it is hard to say that any tract can not be reclaimed.

When the underground water is developed and all possible storage availed of I feel certain that the small acreage now called "reclaimable" will be greatly increased. Suppose we bring water from the mountains and irrigate the first bench, and run a channel along its base, we get water enough from seepage to irrigate another tract. The topography offers us the opportunity to utilize water over and over again.

On the benches we come to hardpan at about two feet. This land is, however, on a heavy slope and drains itself. Then below that you generally find another stratum with water. This hardpan is calcareous in character. It is a gravel that has become saturated with running water and puddled. Away from the benches in the valley bottom you generally find a wash, but it is very hard to predict the nature of the substratum; sometimes you find 20 feet of pebbles.

In planting trees on the benches you have to penetrate the hardpan if you wish the trees to thrive. The highest bench does not seem to be the best. There is a middle mesa, or bench—the first bench as we call it—that is the best land in the valley. The next bench is very gravelly, but is suitable for some crops.

As to crops to be raised by irrigation in Utah, I should put wheat and potatoes first, and alfalfa is among the very best. We have had yields of 4 tons of grapes to the acre, and 1,200 bushels of carrots per care. We took the American Agriculturist prizes for wheat, and one of the prizes for the best yield of potatoes. The western flank of the Wasatch comes in for the glory of fruit-raising. In Cache Valley they raise some fruits, but can not compete with us. In the Sevier Valley they try to raise figs, but have not made much of a success. They seem to be cut off from the effect of the California climate by the range. On the Virgin River they can raise oranges. The sugar beet here grows to a great size. We show a constant increase in the annual area of cultivation.

The Government should begin by a very thorough investigation and report upon the whole region to find out the controlling facts. The people living here have demonstrated that irrigation means high cultivation; that we can make an acre of land yield more than an Eastern farmer does. When we get water for our land we are not subject to the caprice of the climate. Forty acres here will support a family as well as 160 acres in Missouri and Illinois, and the Western family will be better supported. In this Territory 8 and 10 acres in staple crops support families. It gives them enough to eat and enough to wear and a sufficient education. My brother told me that for every day's work he put on a 40-acre farm he got $10 a day in return, year in and year out.

Mr. Doremus, city engineer of Salt Lake City, also presents interesting data. He says:

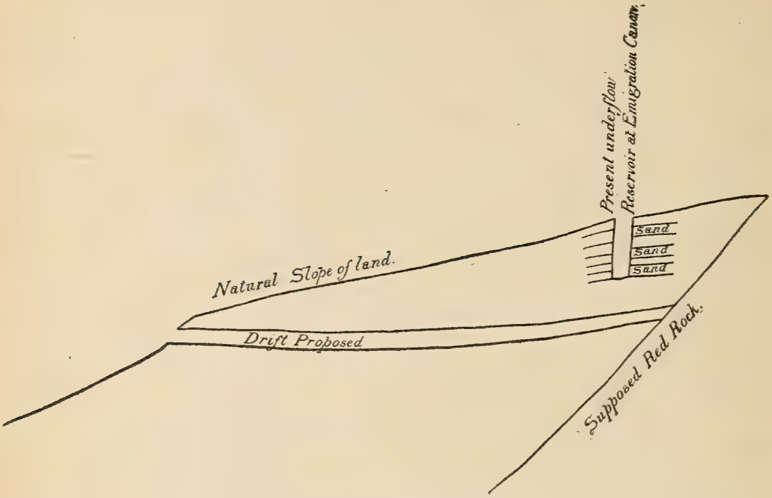
In this valley, in the older irrigated regions, the subsoil will be cemented so hard that a plow can not penetrate it.

At the head of First South street is an excavation made for the city supply. They turned Parley's Creek into the trench and it ran a week without a drop coming to the surface below its line. In constructing sewers and laying water pipes the city engineers find a great deal of trouble from water running under the city with quite a velocity, moving at such a rate that it will wash out cement from the joints of pipes. The water standing in the trenches, roiled and muddy from the operations of the workmen, will clear thoroughly during the noon hour.

At the head of Cottonwood Cañon there are ample facilities for storing water, because there it is a bed of hard granite free from fissures. At the head of Big Cottonwood there are sixteen natural lakes; but probably not more than three or four out of the sixteen would afford means of storing water. Of course, storage would bring up the complicated question of division with the present ditches. This stored water could of course be flumed or taken through another channel.

Irrigation affects the artesian wells and other earth supplies more than the local rainfall. This is shown by the fact that just as soon as irrigation begins the flow of the wells is increased. There is most probably a fissure of geologic fault surrounding the Salt Lake artesian basin. No water comes direct from the mountains into the basin. Often if a man sinks a well a very little lower than one of his neighbors this older and shallower well will cease to flow.

The data furnished by Mr. Culmer as to work at Emigration Cañon is correct. In fact, the experiment has been so successful that there is now proposed a bedrock drift at that point.



Underflow works, Emigration Cañon.

This bedrock drift had not been located but it was confidently expected to afford unlimited supplies of water.

The recent returns to the committee on statistics of the Irrigation Congress which met September 15, 1891, at Salt Lake City show an average waste of 70 per cent of the water used. During the season of 1890, 333,404 acres were actually watered. It is therefore certain that twice that area or 665,808 acres might have been irrigated with the same amount of water had reasonable economy been exercised in distribution and application. Less than one-third of the water actually used under proper conditions would have produced the harvest of 1890. During the same season there were under ditch 735,226 acres. Assuming that the same proportions would apply to the acreage commanded by the canals it is plain that the present appropriation of water in Utah will irrigate all but 833,548 acres of the total estimated area of 2,304,000 acres in Utah. The water in sight and available in Utah is not by any means all appropriated, there being numerous areas large and small in the territory that have sufficient water, but no population or market for its utilization. With due regard to the assertion made on the authority of an official engineer, that only 263,000 acres were irrigated in Utah in 1890, and that that area is about the utmost that can be cultivated without recourse to high mountain storage, the office of irrigation inquiry believes from data in its possession as a reasonable proposition that there is water sufficient, with economic use, to irrigate every acre in Utah upon which it can be made to flow.

This problem is threefold:

(*a*) The economic use by the best known methods of the present surface supply.

(*b*) The development of the immense seepage that flows underground through the cañons and the valleys, and which will continue with or without storage.

(*c*) Storage by dams through the utilization of high altitude lakes, formed in the glacial moraines at favorable spots both in the cañons and on the plateaus.

In considering the future development of irrigation in Utah it must be remembered that the inflow of Great Salt Lake is 7,500 cubic feet per second, sufficient without storage to irrigate 750,000 acres of land. Only a fraction of this amount, however, is at present cultivated. The water is carried to segregated tracts of land without regard to its economical use, the ditches crossing and recrossing and carrying the water down from the bench lands to irrigate the bottoms, paying no regard whatever to the advantages of the local topography. The great bar to future development is that the water rights as now held do not serve the most available land, although a proper diversion of the water in sight will many times increase the irrigable area. A ditch that takes out of the stream 50 cubic feet per second and only delivers 15 or 20 feet to the land is a hindrance to true progress. The owners of water rights must come to some agreement by which larger and more modern canals may be constructed, allowing the diversion of water to the land most available without long stretches of useless main ditch. The acquirement in any neighborhood by an association of the irrigators of all the water rights and sources and a transfer and relation of every right to its proper and nearest source would relieve the art of many of the uncertainties and hardships attendant on the present wasteful system. A much less number of large canals with a minimum of seepage and evaporation would discharge more water for actual use than is now brought to the land by the multitude of small ditches. Now the early settlers or owners of the "prior rights" claim the first exclusive use of water; the surplus is then allowed to those holding secondary rights, and by the time the third or fourth appropriator or new settler is reached there is no water. Useless seepage and evaporation have absorbed 70 per cent of the water taken in at the head gate, and the prior appropriators actuated by natural selfishness have disposed of the remaining 30 per cent. Under this system economy is impossible. The tracts irrigated often bear no economic relation to the source of supply, and the maze of crude supply ditches were constructed to carry as much water as possible to each particular tract, without regard to the fact that the same appropriation in many instances would serve much more land at a point nearer the head gate. One farmer besides a "prior right" may own secondary, third, and even fourth rights in the same ditch, according to the date of first cultivation of different tracts of his land. Primary rights are often not determined with precision, and with all this complication the wonder is that disputes are not more numerous.

Many cures have been suggested for all these evils, most of them requiring the outlay of vast sums of private or municipal capital; but it must be apparent that any benefit to be lasting must as a basis seek the improvement of the present system. False economy must be eradicated, bad construction replaced by good, and above all the irrigators must be informed of right methods. In Utah a small army of men, with prodigal expenditure of labor and water, have reclaimed a small portion of its great arid area, and at the present time high altitude storage of storm water would only intensify the evil, because it would now have the sole effect of giving more water to be wasted in the proportion of 7 cubic feet per second for every 3 applied to the land.

This strong presentation of the irrigation status of Utah is made in a spirit of absolute fairness. Census Bulletin No. 35, entitled "Irrigation in Utah," after a special plea for the necessities of mountain storage, says:

> Owing to the difficulties and uncertainties concerning the supply and distribution of water, many farmers in the northern counties have gone to the extreme of declaring that dry farming is preferable wherever it is possible. Cereals can be raised to a greater profit than by irrigation, although the yield per acre is less.

Intimate personal knowledge and a voluminous correspondence has failed to reveal to the office of irrigation inquiry a single farmer who prefers dry farming to that by irrigation. Upon the very face of the case every drop of water applied to the ripening crop means additional profit to the farmer. If the land has a water right the additional annual expense in Utah is 91 cents per acre for water; if water is not worth this amount then irrigation is a failure. The statement is only noticed because of its connection with many others, all tending to cast the shadow of doubt on present and possible sources of supply. The primary fault in Utah is that the "water in sight" is misapplied; that is, it is directed to certain tracts, not on account of accessibility to the source of supply, but because the owner desired a "prior right" to water, no matter how far he had to go to get it; and the water is consequently wasted. The correction of this evil can only be accomplished by Utah irrigators through proper legislation.

To exhibit some of the past and present physical and economic conditions that environ the irrigator in Utah and influence his actions, the following condensed interviews between prominent local irrigators and the special agent are herewith presented:

Mr. E. G. Wooley, bishop in the Mormon Church, came to Utah in 1850, and like the balance of the Mormons knew nothing about irrigation, as they all came directly from humid regions.

> "The Pioneers" came into the valley in July, 1847. The advance company drifted right down upon the site of Salt Lake, coming through Emigration Cañon.
>
> They went to work the first day, ran a plowed ditch out of City Creek, and started the water out on the ground, and planted some potatoes the same day. That was the first irrigation.
>
> In planting corn we adopted the methods of plowing while the ground is moist in the spring, and then when the time for irrigation came we would open a deep furrow at the head of the field and let the water down shallow furrows between the rows.
>
> In making a settlement we always locate the town on the higher and dry land, and the people live in the community.
>
> Mount Wooley has a large dam situated about 4 miles east of Washington, in Washington County, and about 8 miles east of St. George on the Virgin River. It was first built of rock, dirt, and some brush. Some three years ago we built a dam by driving spiles down and filling in with brush and dirt; but the river is subject to very heavy floods and is full of quicksands, and about a year and a half ago this dam was washed out. Though discouraged, the people decided to make another effort; so they went up the river where the sides are solid rock and low on one side, and they cut a spillway on the north side. The spill is 100 feet in width. We then went to work and built a tight dam across the river, throwing the water through this rock spill, which saves all chance of too great a rise in the river. In putting this new dam in it was calculated that by building a ditch costing about $20,000 they can irrigate 1,000 acres of land. The dam will also cost $20,000. It goes right round the base of the cliff in the solid rock. Where the water is taken out into the ditch the river is dry, but 100 feet below the dam the water begins to seep back, and gradually fills, so that as much water is flowing below our tight dam now as before the dam was built.
>
> At La Verken we have taken out another ditch and tunnel, about 4 or 5 miles south of Toqueville and we irrigated about 800 acres then. In this case we went up

to the gorge of the cañon and put in a temporary dam, and brought the water right out under a rocky cliff; then tunneled through a ridge for about 800 feet, and brought the water out on the bench or mesa land 150 feet above the river bed. This then irrigates 800 acres devoted to semitropical fruits. We can not raise oranges, but grapes, prunes, apricots, pears, etc.

We do not use now in any of the older settlements one-fourth the water that was necessary when the land was first irrigated.

Mr. Frank L. Hines, well driver, Salt Lake City, has been in Utah Territory twenty years, and has resided steadily within 20 miles of Salt Lake City for eighteen years. He states that:

The artesian basin embraces the whole of Salt Lake Valley. In North Salt Lake addition within the city limits, I sunk a well on October 14, 1888, and only had sulphur water at 280 feet. We found there was water but no flow. The strata are: bowlders right in the grass roots for 100 feet, gravel 50 feet, sand 45 feet, hard pan 46, and cemented bowlders for 152 feet. We struck hot sulphur water at 162 feet, and found it in loose gravel in the cement. This well is north from the center of the city 3 miles, straight out Second street west.

E. B. Wicks, Poplar Grove, has a well 3 miles west and south of city, in sec. 1, R 1 S., T. 1 W. The stratum bored was as follows:

	Feet.
Sand and clay	40
Quicksand	120
Clay	4
Sand	100
Clay	3
Sand	120
Hard pan	6
Total	393

Water is found in coarse gravel. Out of this well wood, sheep, and rabbit excrements were taken at 325 feet. It yields 125 gallons per minute by 5-inch pipe.

The Burlington Syndicate well is located on sec. 1, R. 1 S., T. 1 W. The drill passed through—

Surface clay and sand, 6 feet.
Quicksand clean down.
At 160 feet, small flow, about 10 gallons per minute.
At 185 feet, small flow, about 10 gallons per minute.
At 325 feet, small flow, about 50 gallons per minute.
At 452 feet, small flow, about 75 gallons per minute.

Flows through a 4-inch pipe.

City well, No. 1, in Liberty Park, on sec. 1, R. 1 E., T. 1 S. Its strata is as follows (8-inch pipe):

	Feet.
Loose gravel	60
Cemented bowlders	40
Clay	16
Total	116

Water in coarse gravel, 212 gallons per minute.

City well, No. 2, in Liberty Park, with 8-inch pipe, shows:

	Feet.
Gravel and loose shale in alternate layers	130
Cemented bowlders	70
Loose gravel	66
Clay	6
Total	272

Water flows 350 gallons per minute.

City well, No. 3, in Liberty Park, has an 8-inch pipe.

	Feet.
Gravel, shale, red sand, and clay, alternate layers	375
Hard cemented gravel	175
Total	550

Water in coarse loose gravel, 500 gallons per minute. Wood was cut through at 500 feet; it must be from a log a foot or more in diameter. Shells came up with the water. Wood looked as if it had been charred by fire. These three wells are within 70 feet of each other in a line running north and south.

City well, No. 4, in Liberty Park, with 8-inch pipe. Strata same as No. 3; that is—

	Feet.
Gravel, shale, red sand, clay, in alternate layers to	325
Water-bearing sand	380
Thin clay to	400
Total	1,105

With water in coarse gravel. This well is 60 feet from No. 3 and flows 350 gallons.

City well, No. 5, in Liberty Park.

	Feet.
Loose gravel to	110
Clay	15

Good water, with sufficient pressure to take it up to tank 15 feet above surface at the rate of 150 gallons per minute. It flowed 4½ inches above 8-inch pipe at the rate of 700 gallons. This well is about 550 feet north and west from No. 1.

Perkins Addition well is about a mile from No. 5 well.

Soil and clay 8 feet. From that point down to 120 feet it is cement. It has gone no farther, but the bore is still in the hole. In this same field there are twelve other 2-inch wells, all the way from 26 to 250 feet, and all flowing at an average of 15 gallons per minute.

It is mere opinion, of course, but it is the result of nearly twenty-one years' experience, that if a well is sunk to bedrock so as to get the underflow of Emigration Cañon and Parleys Cañon, a flow of 2,000 gallons per minute might be secured. The same is true of all the other cañons.

There is an immense amount of water flowing into the Salt Lake Basin from the cañons. This is plain to anyone knowing the topography of these mountains. Take Parleys Park, at an elevation of 3,300 feet above sea—a great mountain meadow—which is full of water; 3 feet from the surface it can be obtained in large quantities. Then there is Bonanza Lake, 10,000 feet above sea, which has no visible outlet. Then later the mining tunnels show a great deal of water, as for instance at the Ontario, where the vein is in the contact between the quartzite and porphyry, one tunnel is 600 feet and another 1,000 feet. The Anchor mine has a tunnel in there of 1,300 feet, the Alliance another of 1,800, all of which discharge large quantities of water into this meadow called Parleys Park. To tap this immense supply, say at a point near Park City, would require a tunnel 30 miles, but large supplies coming down in the underflow of the cañons from such sources may be developed at little expense near their mouths. These meadows, or mountain sources, are also the principal feeders of the artesian basin.

Sandy well, at the Mingo smelter, is situated in the wash at the mouth of Little Cottonwood, and sinks 1,485 feet into the cañon wash all the way down. This well is sunk on top of a hill, and where the drill starts is 500 feet above Salt Lake. At about 300 feet deep we struck the first flow.

Mr. Hines has three ranches, two of them irrigated from artesian wells. One ranch is 80 acres, watered by five wells running from 1¼-inch bore to 6 inches. He irrigates 17 acres of potatoes from 2-inch wells flowing combined about 120 gallons per minute, leaving a large surplus of water which he proposes to put on other crops. The water is caught in a reservoir about 1 acre in extent, and 4 feet deep, and from that distributed to the crop.

Col. John R. Winder, of the Bishop's office, Salt Lake City, stated that he came to Utah in 1853. The first irrigation was done from City Creek. The natural flow of the creek was utilized and the water was taken out in laterals over the soil from the sides of the stream. The first ditches were called Kenedy's ditch and Winder's ditch, and were small ditches about 4 or 5 feet wide and 18 inches deep. They were taken from Parleys Cañon. Emigration ditch, of about the same size, was constructed very shortly after. They were all made about 1848.

The Kenedy and Winder ditches are now about 10 feet wide and 18 inches deep; they irrigate about 3,000 acres.

In the beginning we used to have to irrigate wheat to get it up out of the ground, now two irrigations will mature the crop, and the lower land has the seepage from the irrigation of the bench lands. They irrigate only on the high bench lands now as the bottoms are full of water.

The first large canal that was built was the Big Cottonwood. It was built for the purpose of carrying rock to our works, but it was afterwards used for irrigation. It has a fall of 20 inches to the mile, is 20 feet wide on bottom and is 3 feet deep. This canal is on the east side of the Jordan, and it has been merged into what is called the Salt Lake City Canal.

The next canal was the North Jordan, which irrigated the land west of the river. The next was the South Jordan, which goes higher up and takes a better volume of water. The next is the Utah and Salt Lake Canal. These three lie one above the other.

In the vicinity of the city the whole plateau was laid out in 5 and 10 acre lots, but as you went down further into the country the farms would increase in size up to 20, 25, and 30 acres, and sometimes more.

Each canal has a board of directors and they appoint officers. They have one or more superintendents, as the case may be. These superintendents make an estimate of the amount of work they will have to do during the year, and levy an assessment on the stock at so much per share. The shares of stock represent an acre of land and water to irrigate it.

Col. Wilder sunk the first artesian well in the valley. It is a 6-inch bore down 78 feet, with a flow of about 75 gallons per minute. He also drove a second well near the first. When the second was down to the 78-foot level the water in the first stopped. The second well was driven 2 feet further and the water returned to the first well.

Jesse W. Fox (Mormon), ex-surveyor-general of the Territory, stated that—

They commenced irrigation in this valley by leading the water from the main stream above the farming plane to the land. They were taken out on both sides of the stream at intervals convenient for irrigation. At first these were plow furrows and shallow dry ditches. When I came here the irrigation was mostly confined to Salt Lake and Davies counties, and did not exceed 14,000 or 15,000 acres.

The first large canal was taken out in 1870-'71-'72, called the South Jordan. It has been since enlarged and extended. It was originally 6 feet on bottom, 2 feet deep, and 32 inches fall per mile. Its present size is 15 feet on the bottom and 4½ feet deep, and 32 inches fall per mile.

The next was the Utah and Salt Lake Canal, on the west side of the Jordan. The calculation was to set slack water back to Utah Lake, making that lake a reservoir. That canal is 20 feet wide on bottom, and carries 4 to 4½ feet of water in the banks.

The next is the North Jordan Canal, which was located about 1872. It is 12 feet wide on bottom, and carries 4½ feet of water. These three canals are on the west side of the river Jordan, watering the land from the river to the mountain range. On the east side is the Draper Canal, located in 1873, which is 15 feet bottom width. These canals are all 1 to 1 and 1 to 1½ slope.

The irrigation of Salt Lake City was from City Creek, but we have now appropriated the waters of this creek for city purposes, and have constructed a canal from the Jordan River to supply the irrigation formerly had from City Creek. That canal was located in 1880. It is called the Jordan and Salt Lake City Canal. It is 20 feet on bottom, 4½ feet deep.

These are the principal canals, but there are others taken out from Red Butte, Cañon Creek, Mill Creek, Big and Little Cottonwood. The canals named were the first located in Utah.

The duty of water in this Territory has increased at least 30 per cent, without considering the lands moistened by seepage.

Of the canals named, the first five were incorporated, having a capital stock, which stock was principally paid for in labor, only a few paying in money. A share of stock represents water for an acre of land.

H. S. Josephs, C. E., Salt Lake City, stated that—

In NW. ¼, sec. 23, T. 2 N., R. 1 W., is a bore 580 feet deep, and no water. In section 22, same range and township, there is a fine well, having about 60 gallons flow. In section 14 there is another, 175 feet deep, that gives about 15 gallons per minute. This is sulphur water. In the same section there is another well, 175 feet deep, furnishing perfectly pure water. This well is in the northwest corner of the section. On the north line of the same section, about half a mile from the last well, there is another that goes down 400 feet, but water has been struck.

In section 11, a little to the north of the center line, there is a well which is rather curious. It went down to 240 feet, and struck water that rose to within 40 feet of the surface. The other day the owner put a pump on to try and pump it out, when the water disappeared altogther, although it had been standing within 40 feet of the surface.

In the Escalente Desert we sunk a well at Sulphur Springs, which has a very good flow. In Sec. 6, R. 14 W., T. 33 S., they went down 650 feet, and only got water standing in the bore. At Iron Creek Cañon water can be got from flowing wells sufficient for irrigation. At the other points I do not doubt that a man would get good water if he went deep enough. The land in Salt Lake Valley is best adapted for grape land, both on account of soil and because grapes need less water than grain.

Mr. Fred. Trimmer, C. E., of Salt Lake City, Utah, stated that—

It is believed that in Salt Lake Desert there are underground waters. Here is the Great Salt Lake, with an area of 1,200,000 square acres. It is ridiculous to say that the vast amount of water flowing into this lake to maintain and constantly increase its level is only sufficient to irrigate 260,000 acres of land unless high mountain storage is resorted to. The great thing we need in this country is to find out more about the under or subflow; to find its channels to the lake, and take it out before it becomes salt.

The total amount of water flowing into Great Salt Lake is sufficient to irrigate 600,000 acres. That at the rate of a cubic foot per second for 100 acres would only be enough to put half a foot of water over the lake basin per annum. Now we are told that the evaporation is 4 feet 5 inches per year over the whole surface of the lake. That certainly demonstrates that there must be a large supply from some invisible source.

S. Richardson, of Richardson, Grand County, Utah, stated in illustration of the extent of the surplus or flood waters that in May he crossed the Grand River in Utah, 13 miles due south of Cisco, on the Rio Grande Western Railway, and it was running 20 miles an hour, 1,000 feet wide, and 18 feet deep. From his knowledge he considers Utah quite well watered, especially the eastern portions. "There is water enough," he said, "going to waste to put at least one million acres of land in southeastern Utah under cultivation. This is no exaggeration. A man has only got to be there to see it. The great drawback to agriculture and irrigation there is want of transportation. The average altitude is 4,500 feet."

One of the great irrigation enterprises and works is that of the Bear River Canal, which is diverted from the river of the same name about 3 miles above Colliston. The system, when completed, will have 150 miles of main canal and principal distributing canals and ditches, with laterals sufficient to irrigate 200,000 acres of land. At the point of diversion two main canals are projected on the east and west banks of the river. About 60 miles of main canal are completed, and nearly as many more of distributaries, with flumes, headgates, regulators, and other works. About 8 miles of heavy rock work in the cañon has been completed, so as to enable the canals on either side to carry the water out into the broad valley lands. Maximum flood discharge at weir site is about 8,500 second-feet; average minimum about 1,000 feet during midsummer. The diversion weir is located between high rock abutments, with its foundations in shallow rock. The weir is of crib work filled with earth and loose stones to a height of 17½ feet. The abutments widen toward the top, so that the length on the crest is 370 feet, as against 98 feet at the base. The timbers are 10 by 12 inches and built to the rock bed. There are 5 headgates, 4 feet wide by 7 feet high, made of iron, on the west side, and the same number on the east side canal, which latter for 2 miles is in heavy rock work. There are two tunnels 14 by 14, inclined, with a total length of 623 feet. The engineering is very bold, Several deep cuts have been made, the deepest being 96 feet on the upper side. In this portion of the canal a considerable length of rubble retaining wall, laid in cement, is constructed, quite 10 feet high on the inside, 2½ feet thick at top, and 7½ feet at the grade line. Heavy fills are made across ravines, which are drained by means of culverts carried through the banks. One of these is 108 feet in depth at the center and 508 feet long on the grade. On the top rests a wooden flume, which carries the canal water. It is supported by long piling driven 60 feet into the fills.

In the level country this east side canal will have a bottom width of 50 feet and a depth of water of 7 feet, side slopes of 1 by 1 and a grade of 1 foot to the mile. It will be 50 miles in length, terminating at the Ogden River, Ogden, Utah.

For the first mile and a half on the west side it is constructed in heavy rock in a similar manner. There are six tunnels varying from 57 to 267 feet in length, with the same cross section and grade as on the east side. Above and below the tunnels are eleven retaining walls similar in construction to those on the other canal. The canal has a bed width of 14 feet 3 inches and a depth of 10 feet, with nearly vertical slopes; 1,200 feet below the head is an escape gate and a second one 600 feet further, discharging into the Bear River, with clear openings of 12 feet wide. They are closed by wooden gates sliding between iron posts let into masonry piers. Below the second escape is a regulator, with five gates 14 feet in width, constructed for the purpose of controlling the discharge in the canal. Six miles beyond this canal enters a hillside excavation of a very bold character. The bottom width remains the same.

The canal crosses the Malad River at its ninth mile, on an iron bridge with flumes 378 feet in length and 80 feet in maximum height, supported on iron trestles, having a river span of 70 feet. The approaches to the bridge are wooden flumes 500 feet in length and 20 feet wide in the clear and 7 feet deep. The flume over the bridge is also wooden and of the same dimensions. There are three falls of 7 feet each. This canal terminates at Salt Lake.

Six miles below the head of the west side canal a branch is diverted to Corinne. It runs 20 miles at its head, it is 22 feet wide on bottom, and carries 5 feet of water and is controlled by a double set of regulation gates. Both in the main and Corinne Canals the bottom and sides are protected by wooden wings. In the Corinne branch there are 16 vertical falls varying from 4 to 12 feet in height. The Malad River is crossed 14 miles from the head, on an iron bridge founded on piles and iron cylinders founded on concrete. The peculiarity of the bridge is that its superstructure, which is of iron-plate girders, constitutes the flume for carrying the water, with wooden flumes in the cab on either side. There are several inverted siphons or culverts of wood on this line, carrying the drainage under the main canal. One of them consists of two tunnels of 8 by 8, which have a clear waterway of 5¾ by 2½.

During the past year, 1891, there has been constructed what is known as the North Point Consolidated Canal, which adds 14½ miles to the ditches on the west side of the Jordan River. The bottom width is 50 feet for the first 3½ miles of its length, and the remainder varies from 20 to 15 feet bottom width. It will carry 93 cubic feet per second. The duty of water on the soil irrigated is 150 acres to the second foot, and it will therefore increase the irrigation in this valley 14,000 acres.

The Swan Lake Reservoir and Canal Company is a recent enterprise which is still in process of construction. It consists of a reservoir fed by the Sevier River, covering an area of 70 square miles, and located in the central portion of Millard County, 5 miles from the Union Pacific Railway and 15 miles northeast of Sevier Lake or Sink. This reservoir consists of a number of natural depressions, requiring only slight construction work to appropriate and adapt them to the requirements of the reservoir.

The continued action of the river current has built up walls or natural levees which rise to a height above the surrounding country like the levees of the Mississippi and other streams. The company in constructing their reservoir repair the natural walls, build strong dikes across channels, cut ditches and canals, build dams and flumes. There are at present over 200,000 acres of level, fertile, and irrigable land lying under the reservoir supply. About 15 miles of canal have been completed.

The lake reservoir when full will hold about 3,500,000,000 cubic feet, or 200,000 acre feet. In May, 1891, when the river had its rise, the flow over the waste dam was 30,000 miners' inches. The irrigable land is underlaid with clay a few feet below surface. The area to be reclaimed is estimated at 75,000 acres.

Another enterprise, begun during 1891, contemplates the control of Utah Lake, and is known as the Oquirrh Water and Land Company. It has for its object the lowering of the Jordan River at the outlet and below Utah Lake. The present river bed is much higher than the bottom of the lake and acts as a bar to the lowering thereof and to the obtaining of a large supply of water that can not now be utilized, and which when so utilized will be restored in the winter. Such a lowering will, it is claimed, also admit of a better regulation of the rise and fall of the lake. This lowering of the outlet will permit the irrigation of possibly some 25,000 acres, and by storing in the Provo River this can be still further augmented. There are some objections and criticisms raised against these propositions.

In cities the municipal corporations control the waters, watermasters being appointed to regulate the division of the water. The following synopsis of laws relating to Utah were compiled and furnished by Col. Charles L. Stevenson, C. E., president of the Polytechnic Society of Salt Lake City:

Whenever public necessity requires it, the county court may organize the county, or part of it, into an irrigation district, and the landholders therein may use the water brought into the district according to their respective needs, provided they pay and perform their proportion of the necessary expenses and labor. They may, on due notice, elect trustees, a secretary, and a treasurer.

The trustees shall locate the ditches and estimate all costs and reports to the county court. If the report be approved by a two-thirds vote, a tax shall be assessed and the ditch constructed.

The trustees have general supervision of the construction, maintenance, and regulation of the ditches; they may hold such personal property as is necessary to the performance of their duties; may sue and be sued, and may have appraised and sell any unclaimed lands that are to be benefited, and apply the proceeds to the construction of the ditches.

Lakes and ponds may be used as reservoirs, provided they are not raised so as to injure settlers upon their banks.

In case of inundation or other sudden emergency the trustees may take measures for protection.

Property and money in the hands of trustees to be used on the ditches is exempt from taxation.

Ditches have the right of way, a proper compensation having been paid.

Any person injuring a ditch or any of its appurtenances is liable in damages and to a fine and imprisonment.

The district is liable for damages caused by the breakage of a ditch.

The rate of tax at any election subsequent to the first may be determined by a majority vote, and the tax thus assessed shall be a lien upon the taxpayer's interest in the ditch and a right to use the water.

By act of February 20, 1880, the selectmen of the several counties are made water commissioners, who have a kind of superior jurisdiction of the water rights in their respective counties.

They determine claims relative to the use of water, oversee either personally or by agents its distribution, and determine questions of right of way, etc.

They also issue certificates showing the extent of water rights.

A person first taking water from any source of supply, or having the open, peaceable, and continuous use of the water for seven years, has a primary right therein to the extent of the reasonable use thereof.

Whenever persons having primary right use the water for a part of the year only, the person appropriating it for the balance of the year acquires a secondary right.

Water rights may be measured in inches or by fractional parts of the whole supply. Water rights may pertain to the land or may be personal property, as the owner may elect, and a change of place shall not affect the right to use the water, but no change of place shall be made to the injury of another owner without just compensation. Neglect for seven years to use water, or keep in repair the means of conveying it, is regarded as an abandonment of the right.

Water rights are exempt from taxation, except for the purpose of regulating the use of the rights, but the increased value of the land may be regarded in making the assessments.

Surplus water must be returned to the natural channel, and any person wasting it is liable to have his supply shut off, and to pay damages to any person injured.

Any person using water lawfully appropriated to another, or diverting the flow of water lawfully distributed, or injuring any dam, ditch, etc., is guilty of a misdemeanor.

Whenever the supply is not sufficient for all purposes, the use for domestic purposes and for irrigation purposes takes precedence in that order.

Corporations may be formed under general laws for distributing water to their stockholders.

STATISTICS OF IRRIGATION IN UTAH.

The meeting in Salt Lake City of the Irrigation Congress gave activity to the collection of data. The following table, prepared by Charles L. Stevenson, C. E., of Salt Lake City, is presented here with the indorsement of this office. The methods of collection are known, and the care and pains devoted to the proper presentation of the same appreciated. The total given of total acreage of "irrigable lands" is of course understood to be an estimate. By many good authorities a much large area is considered available for reclamation. This office agrees with them:

County.	Under irrigation ditches.	Actually irrigated, 1890.	Cultivated, 1890.	Irrigation season begins.	Irrigation season ends.	No. of times lands irrigated during season.	No. of hours land is irrigated each time.	Elevation above sea.	Depth of snow in adjacent mountains.	Duty of water per cubic foot per second.
	Acres.	*Acres.*	*Acres.*					*Feet.*	*Feet.*	
Beaver	9, 000	6, 359	6, 350	May 15	Aug. 15	8	24	5, 000–6, 000	4	......
Boxelder	120, 695	9, 708	26, 177	May	August	8	1½	4, 000–5, 000	3	......
Cache	66, 654	30, 951	54, 301	....do	September	8	4	4, 500	3	150
Davis	19, 530	10, 591	23, 161	April	October	10	2½	4, 200–5, 000	3	......
Emery	23, 415	13, 062	14, 363	March	November	......	......	3, 900–4, 500	4	......
Grand		1, 375	1, 416	Apr. 15	Oct. 1	......	......	5, 800–6, 300	......	......
Garfield	12, 029	7, 635	8, 635	April	August	8	5	6, 500	3	......
Iron	8, 197	3, 956	4, 523	....do	November	6	6	5, 000–6, 000	4	80
Juab	8, 100	4, 914	9, 489	May	September	10	......	5, 500	8	......
Kane	1, 463	722	1, 087	Apr. 1	October	8	12	5, 500	......	75
Millard	88, 586	8, 152	8, 152	Apr. 15	Aug. 15	......	......	5, 500	3	......
Morgan	7, 924	5, 633	5, 633	May 20	Sept. 1	7	......	4, 000–5, 000	6	100
Piute	17, 172	9, 918	9, 918	April	September	5	8	5, 000–7, 000	4	......
Rich	31, 484	26, 099	26, 099	....do	August	3	3	6, 000	5	......
Salt Lake	53, 086	29, 107	30, 555	May 15	Sept. 15	8	......	4, 300	6	100
San Juan	1, 107	927	927	......	......	......	......	5, 000	......	......
Sanpete	45, 102	33, 859	47, 113	May 15	September	5	24	5, 550	6	95
Sevier	29, 106	15, 340	15, 340	April	October	5	12	4, 000–7, 000	......	......
Summit	18, 743	14, 550	14, 550	May	September	3	......	5, 845	5	......
Tooele	14, 400	5, 343	7, 524	March	... do	......	......	4, 600	2	80
Uintah	17, 826	10, 054	10, 054	April	October	......	......	4, 600	6	......
Utah	79, 380	53, 586	60, 520	March	September	8	......	4, 600	4	......
Washington	9, 533	4, 203	4, 203	April	October	12	3	2, 700–5, 000	4	40
Weber	33, 344	17, 004	22 450	May	...do	12	2	4, 500	2	......
Wasatch	19, 350	10, 365	10, 824	......	......	......	......	6, 000–7, 500	6	......
Total	735, 226	333, 404	423, 364	......	......	......	......	......	......	......

NOTE.—The total acreage of irrigable lands in Utah Territory is.... 2, 304, 000
The total acreage covered by present ditches is.............. 735, 226

The total additional acreage susceptible of irrigation is..... 1, 568, 774

Joseph Lippman, Territorial statistician of Utah, in his first annual report to the Territorial secretary, presents the following table and explanation, showing by counties the number of acres under cultivation, the number of acres irrigated, and the number of acres under inclosure for pasture in Utah during 1890. In a few instances the figures show a greater number of acres as irrigated than are given as cultivated in a particular county. This is explainable on the theory that many farmers do not look upon the raising of alfalfa, although it requires irrigation, as a cultivated product, and hence, while they have included the alfalfa field in the "irrigation acreage," they have not included it in the "cultivation acreage" returned to the county assessor.

Number of acres under cultivation, irrigated, and under inclosure for pasture.

Counties.	Under cultivation.	Irrigated.	Under inclosure for pasture.	Counties.	Under cultivation.	Irrigated.	Under inclosure for pasture.
	Acres.	*Acres.*	*Acres.*		*Acres.*	*Acres.*	*Acres.*
Beaver	5, 558	6, 350	2, 161	Salt Lake	30, 555	29, 107	14, 415
Boxelder	26, 177	9, 708	35, 938	San Juan	809	927	2, 005
Cache	54, 301	30, 951	23, 378	Sanpete	47, 113	33, 859	11, 185
Davis	23, 161	10, 591	12, 232	Sevier	8, 118	15, 340	6, 185
Emery	14, 363	13, 062	3, 223	Summit	14, 508	14, 550	702
Garfield	1, 716	1, 990	1, 145	Tooele	7, 524	5, 343	11, 367
Grand	1, 416	1, 375	2, 827	Uinta	8, 960	10, 054	1, 943
Iron	4, 523	3, 956	1, 098	Utah	40, 195	36, 586	16, 008
Juab	9, 489	4, 914	7, 372	Washington	4, 203	4, 203	....
Kane	1, 087	722	4, 931	Wasatch	10, 824	10, 365	352
Millard	8, 152	8, 152	7, 308	Weber	22, 450	17, 004	17, 107
Morgan	5, 633	5, 633	3, 120				
Piute	7, 779	9, 918	3, 425	Total	374, 340	310, 759	205, 895
Rich	15, 726	26, 099	16, 468				

Mr. Stevenson's figures are based upon reports from officers of the Mormon Church, while Mr. Lippman's were gathered through the usual territorial channels. The figures of the United States Census Office, as presented in Bulletin No. 85, are given below. They relate to the crop and acreage of 1889-90, but only include the irrigated portions of the areas under cultivation.

Utah irrigation statistics in the United States census for 1890.

Counties.	Number of irrigators.	Total irrigated acreage in crop.	Average size of irrigated farms, in acres.	Average value of products per acre.	Counties.	Number of irrigators.	Total irrigated acreage in crop.	Average size of irrigated farms, in acres.	Average value of products per acre.
Beaver	260	7,682	38	$9.92	Salt Lake	1,264	25,392	20	$26.73
Boxelder	359	10,472	29	15.25	San Juan	38	777	20	27.95
Cache	908	30,923	34	14.30	Sanpete	1,155	30,938	27	15.18
Davis	585	12,866	22	32.93	Sevier	311	11,547	37	11.53
Emery	264	7,344	28	17.01	Summit	276	10,140	37	15.03
Garfield	82	2,234	27	11.64	Tooele	267	5,766	22	14.46
Grand	56	1,139	20	19.05	Uinta	186	7,611	41	10.61
Iron	193	3,539	18	14.94	Utah	1,161	25,236	22	22.50
Juab	85	1,946	23	11.05	Wasatch	259	6,475	25	10.22
Kane	107	1,798	17	21.81	Washington	176	2,251	13	32.19
Millard	304	8,199	27	14.58	Weber	928	21,335	23	22.72
Morgan	233	5,298	23	18.16					
Piute	143	5,299	37	11.03	Total	9,724	263,473	27	18.03
Rich	184	17,266	94	9.00					

The totals of agricultural products, quantity, values, and of acreage for 1890 are also taken from Mr. Lippman's report:

Products.		Quantity.	Average to acre.	Acres.	Value.
Wheat	bushels	2,409,454	22	110,114	$1,927,563.20
Oats	do	1,132,218	34	32,763	532,142.46
Corn	do	165,067	19	8,776	118,848.24
Barley	do	212,546	29	7,358	166,273.00
Rye	do	45,204	12	3,759	27,574.44
Lucern	tons	306,100	3	101,729	2,715,107.00
Hay	do	120,572	1.49	80,647	1,637,367.76
Potatoes	bushels	935,874	119	7,845	496,013.22
Beets	do	21,726	248	87	7,604.10
Cotton	pounds	4,200	600	7	462.00
Orchards	do	8,246,062	1,563	5,275	206,151.55
Vineyards	do	565,560	2,134	265	33,933.60
Other products, vegetables	do	16,688,841	6,426	2,597	500,665.23
Totals				361,222	8,309,705.80

This shows an acreage value per acre of crop production in 1890 on irrigated and unirrigated land combined of $22.19 per acre. The total average presented by the Census Office in "Census Bulletin No. 85, Irrigation in Utah," $18.03 per acre, value of product on irrigated land, is in striking variance with this. A careful and conservative estimate will raise the value of the average product of irrigated land in Utah to at least $23 per acre.

The following average yields per acre in staple crops, taken from the same report, will be of interest.

Product.	Average yield per acre throughout the Territory.	Average price per unit of measurement.	Value per acre.
Beets	248 bushels	$0.35	$86.80
Cotton	600 pounds	.11	66.00
Potatoes	119 bushels	.53	63.07
Lucern	3 tons	8.87	26.61
Hay	1.49 tons	13.58	20.23
Wheat	22 bushels	.80	17.60
Oats	34 bushels	.47	15.98
Barley	29 bushels	.50	14.50
Corn	19 bushels	.72	13.68
Rye	12 bushels	.61	7.32

The total value of all outputs of "ranch and range," besides those named before, are given by Mr. Lippman as follows:

Wine	$28,697.40	Dried peaches	$19,645.23
Cider	21,478.80	Dried apricots	1,486.88
Vinegar	6,976.75	Dried plums	841.38
Sorghum	37,440.00	Dried pears	992.10
Butter	323,303.23	Wool	1,229,456.58
Cheese	37,181.25		
Honey	76,894.83		1,796,224.45
Dried apples	11,830.02		

Withholding the wool product from the sum total given, the figures will be a little in excess of the total values of agricultural products already given. These totals speak well for the industry and thrift of the farmers of Utah, and they indicate what may be expected of the Territory and its population as the water supply thereof and its economic management is better understood and more intelligently administered.

Elevations above sea level of prominent locations in and near Salt Lake City.

United States monument, southeast corner Temple Block	4,357.23
Bench mark, odd tank, City Creek, southwest corner of reservoir	4,495.64
Bench mark, stone door step, buck tank, Lown system, City Creek	4,578.86
Surface of water buck tanks	4,577.90
Surface of water tank, north bench system	4,712.40
Surface of water, Capital Hill system	4,746.05
Platform new reservoir First South street east	4,587.70
Proposes surface of water, same reservoir	4,587.10
Bottom of Parleys Canal, First South street crossing	4,744.60
Pipe line (14-inch) Emigration Creek, First South street	4,755.00
Pipe line (14-inch) Emigration Creek, Wagoner's Brewery	4,965.00
Pipe line (14-inch) Emigration Creek gate house	5,051.00
Liberty Park Wells, flume crossing, Seventh street east	4,295.00
Corner of Ninth North street and county road	4,283.00
Denver and Rio Grande western station	4,252.00
Denver and Rio Grande western station, Provo	4,544.00
Bench mark and shore, Utah Lake, Thompsons Baths	4,517.35
This bench mark is 4 feet 3½ inches above lowest water in 1889.	
Highest water, Utah Lake, June 5, 1890	4,517.47
Lowest water, Utah Lake, October, 1889	4,513.06
Trimpanagac River, monument road	4,855.92
Surface water, Trimpanagac River	4,845.41
City Creek, mouth of cañon	4,361.00
Emigration Creek, mouth of cañon	4,919.30

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers received to circulars sent by this office:

CACHE COUNTY.

Logan (post-office), J. W. Sanborn, Agricultural College (September, 1891):

Area of arable land (in county), 200,000 acres; irrigable land, 150,000 acres; irrigated land, 100,000 acres; 50 acres by artesian wells.
Water supply: Streams from Wasatch Mountains, through Logan and other cañons and artesian wells.
Works: About 206½ miles ditches, various sizes. One reservoir at Newton; capacity, 25,000,000 cubic feet; 40 head gates for Logan, Hyde Park, and Smithfield, or 6 miles of canal; about 100 artesian wells, mainly for stock, but about 50 acres irrigated by them.
Cost per mile of ditches: "Most costly one, through ledges, $12,500 per mile;" others vary, down to very low cost.
Average cost per acre of works: Ditches, etc., from $5 to $15; average, probably $8; cost of each watering, 12½ cents per acre; annual maintenance and repairs small; cost per acre of furrow ditches over fields for flooding, from 10 cents to 50 cents.
Products: Alfalfa, clover and grass, wheat, oats, corn, sorghum, potatoes, etc.; some fruits.
Yield per acre: Alfalfa, 3 to 6 tons; grass, 2½ tons; wheat, 30 bushels.

Hyrum (post-office), H. P. Hansen and A. P. Rose (October 1, 1891):

Water supply: Two mountain streams, Blacksmith Fork and Little Bear River, supply sufficient in ordinary seasons.
Irrigation works: About 20 miles ditches; from 4 to 8 feet on bottom; 8 to 12 feet on top; many head gates. No reservoirs, but they are needed badly, and settlers are not able to build them.
Average cost per acre for their main ditch, $2.50; annual maintenance and repairs, $1.25 to $1.40 (including irrigating).
Area irrigated in this precinct: About 4,000 acres; also 600 city lots, each 1¼ acres, which are irrigated once a week for three months, at a cost of $6.
Products: Wheat, oats, barley, potatoes, and other vegetables; also fruit of various kinds.
Estimated value of annual product per acre, $10 to $15.

DAVIS COUNTY.

Kaysville (post-office), Elijah Laycock (September, 1891):

Water supply of neighborhood: Four mountain creeks or streams, fed by melting snows, etc.; also artesian wells. Water taken from creeks in small ditches 2 or 3 feet wide. Water supply of these creeks is divided into "primary shares," worth $25 each (share represents water for one acre for the whole year). There are also secondary shares, worth $12.50 each, which take water until June 1 only. (Some shares water a part of the town.)
Cost per mile of ditches, about $100.
Area in neighborhood covered by ditches, about 4,000 acres.
Area under ditch from creek in which Mr. Laycock is interested is about 2,500 acres; under cultivation, 2,000 acres; annual cost for maintenance and repairs for ditches from this creek, not over 10 cents per acre.
Average cost per acre for preparing land for cultivation under irrigation, about $3.
Chief products, wheat, barley, oats, alfalfa, potatoes, etc., and fruit.
Estimated average yield per acre: Wheat, 25 bushels; barley, 35 bushels; oats, 40 to 50 bushels; potatoes, 100 to 600 bushels.

GRAND COUNTY.

Moab (post-office), secretary "Moab Irrigation Company" (September 12, 1891):

Average cost per acre in vicinity for preparing land for cultivation under irrigation, about $10 (clearing and breaking).
Average cost per acre of irrigation works, ditches, etc., about $4 (under that system); for maintenance and repairs, 25 cents.
Area under cultivation, 1,000 acres; 200 or 300 acres under ditch as pasture.
Chief products under irrigation: Alfalfa, fruit, grapes, and corn (in the order mentioned).

Yield per acre and value of product: Hay, 5 tons, $6 per ton; fruit, no estimate; grapes, $1,000; corn, 30 bushels, at $1.20 per bushel.

SALT LAKE COUNTY.

Salt Lake City, Wilford Woodruff, and John R. Park, M. D. (September 1891):

Area in county under ditch, 53,086 acres; under cultivation, 30,555 acres.
Water supply: Streams fed by the melting snows of the Wasatch range of mountains; also artesian wells.
Irrigation works in county, about 175 miles; main canals, varying in width on bottom from 10 feet to 20 feet. No reservoir.
Average cost per acre for works, ditches, etc., $9 to $10.
Average cost per acre for annual maintenance and repairs, 80 cents to $1.
Average cost per acre for preparing land for cultivation under irrigation, $2 or $3.
Cost of water supply to user per acre, $1.50 (under Bear River system).
Chief products under irrigation: All cereals, vegetables, and fruits natural to the temperate zone.

TOOELE COUNTY.

Tooele City, C. A. Herman and John C. Shields:

Water supply: Cañon streams from the Oquirrh Mountains. (District has 800 miner's inches at 6-inch pressure.)
Area under cultivation, 3,000 acres. (There are 50,000 acres of good, arable, vacant land in Tooele Valley, that with a water supply would yield as fine crops as are raised on any irrigated land in the Territory. Two-thirds of the water in this district is wasted by seepage and evaporation, for the lack of flumes, cemented ditches, or conduits, or pipe lines.)
Irrigation works, 20 miles main ditches, from 6 to 8 feet on bottom, 8 to 10 feet on top, from 2 to 3 feet deep; about 50 miles minor or lateral ditches (all ditches plowed and spaded); 3 head gates; small timber dams in cañons; no reservoirs.
Cost of water supply to user, per acre, from $10 to $15 (originally).
Annual rental cost of water, $1.
Cost of ditches per mile: Main, $200; laterals, $50.
Average cost per acre of ditches, etc., $10.
Average cost per acre for preparing land for cultivation under irrigation, $4.
Average cost per acre for annual maintenance and repairs, $1.
Products: Alfalfa, wheat, oats, barley, corn, potatoes, etc., and fruits.
Yield per acre: Wheat, 30 bushels; oats and barley, 60 bushels.

[Mr. Shields (a director in the Tooele Irrigation Company) reports an area of 1,568 acres irrigated by that company. Water supply: Two cañon streams; supply divided into 14 equal parts or shares, each share sufficient to irrigate 112 acres.]

UTAH COUNTY.

American Fork (post-office), T. B. Parker (September, 1891):

Water supply: Wasatch Mountain streams fed by melted snow; supply insufficient with present facilities and methods of use; storage reservoirs needed.
Irrigation works: About 15 miles of ditches; five head gates; no reservoirs or other works.
Average cost per acre of ditches, etc., $20; for annual maintenance and repairs, 50 cents.
Average cost per acre for preparing land for cultivation under irrigation, about $20.
Area under ditch, 4,500 acres; under cultivation, 1,500 acres.
Chief products: Wheat, oats, corn, hay, potatoes, and fruits.

Pleasant Grove (post-office), Robert Thorne, president "North Union Irrigation Company" (September, 1891):

Water supply: Mountain stream; regular flow 10 months; 2 months subject to freshets.
Irrigation works: 8 miles of ditches, 7 feet wide, 4 feet deep; 2 head gates; no other works.
Cost per mile, about $3,000; average cost of ditch per acre, $25.
Average cost per acre for annual maintenance and repairs, $1.
Average cost per acre for preparing land for cultivation under irrigation, $10.
Cost of water supply to user per acre, $25 (cost of ditch per acre).
Area under ditch, 3,000; under cultivation, 1,000 acres.

Chief products: Alfalfa, wheat, corn, oats, potatoes, beans, sugar beets, sugar cane, and fruit.
Value of product per acre: Wheat, 20 bushels per acre, average 75 cents per bushel. Other crops in proportion.

Provo (post-office), Judge J. D. Jones and J. E. Booth (September, 1891):

Provo Precinct: Area under ditch, 25,000 acres; under cultivation, from 15,000 to 18,000 acres. Water supply: Provo River mountain stream with capacity of from 10,000 to 11,000 cubic feet per minute in low-water season, but three times as much in the months of May and June; supply all appropriated; also a large number of artesian wells, 2-inch pipe, 200 feet deep; flow from 20 to 60 gallons per minute.
Irrigation works: Big Bench Canal, 2 miles long, 20 feet wide, 4 feet deep, 10 miles laterals; Hooper Canal, 10 miles long, 8 feet wide, 2 feet deep; Enterprise Canal, 11 miles long, 6 feet wide, 2 feet deep; Lake Bottom Ditch, 6 miles long, 6 feet wide, 2 feet deep; Timpanogas Ditch, 5 miles long, 4 feet wide, 2 feet deep; Upper East Union, 8 feet long, 8 feet wide, 2 feet deep; East Union proper, 20 miles long, 10 feet wide, 3 feet deep, with laterals; also a number of small ditches; one main head gate for each ditch; total main ditches, 60 to 65 miles; ditches generally owned by the landowners.
Cost per mile of ditches, etc., from $500 to $10,000; average cost per acre, from $5 to $30: for annual maintenance and repairs, about $1.
Average cost per acre for preparing land for cultivation under irrigation, $4 to $5; for grazing, about half that sum.
Cost of water supply to user per acre, $10 first cost; $1 to $3 yearly rental cost.
Chief products: Wheat, oats, barley, corn, alfalfa, tame and wild hay, sugar cane, sugar beets, potatoes, and other vegetables; also variety of fruits, etc.

WEBER COUNTY.

Ogden (post-office), L. B. Adams (September, 22, 1891) this:

Davis and Weber Counties Canal Company. Water supply, Weber River (near Devil's Gate, Morgan County).
Irrigation works: 9 miles main canal, 20 feet wide, 4 feet deep; 5,000 feet fluming, 8 feet wide, 4 feet deep; 20 miles of laterals; no reservoirs on main canal; several small ones, 1 to 5 acres each, on laterals; dam on main canal, temporary; no permanent one necessary; three head gates; also drop and waste weirs.
Area under ditch, 10,000 to 20,000 acres; under cultivation, about 8,000 acres.
Cost of canals and laterals, $150,000; cost per acre for maintenance and repairs, 10 to 15 cents.
Average cost per acre for preparing land for cultivation under irrigation, about $5.
Annual rental cost of water per acre, about $1.
Staple products: Wheat, oats, barley, rye, potates, sugar beets, and other vegetables; corn does fairly well.
Average yield per acre: Cereals, 20 to 60 bushels; potates, 200 to 400 bushels.

Pleasant View (post-office), George Barnett (September, 1891):

Average cost in vicinity for preparing land for cultivation under irrigation, from $10 to $12 (more on some land).
Average cost per acre for irrigation works, ditches, etc., $10 or over.
Area in neighborhood under ditch, over 2,000 acres.
Staple products: Wheat, oats, barley, corn, apples, pears, peaches, plums, apricots, strawberries, raspberries, blackberries, etc.
Average yield per acre: Wheat, 25 to 30 bushels; barley, 40 to 45 bushels; corn, 60 bushels (and over); potatoes, 300 bushels or over.

WASHINGTON.

The State of Washington, in the extreme northwest of the Union, fronts west on the Pacific Ocean; on the east it is bounded by the State of Idaho, south by Oregon, and north by British Columbia. Its breadth north and south is 245 miles and east and west 360 miles. Two-thirds is found east of the Cascade Range, which, as in Oregon, bisects the entire State. The eastern portion has an area of about 50,000 square miles, with about two-fifths of the population of the State, and is yearly increasing in importance. Hydrographically speaking, Washington is one of the best-watered areas in the Union. The Columbia, rising mainly in British territory, enters Washington at 117° 40′, passes southward to Spokane Falls, then makes a great bend through Stevens, Lincoln, Douglas, and Okanogan counties, where it turns almost directly southward to Wallawalla, and passes westward therefrom for the balance of the State, making a dividing line between it and Oregon. The Columbia River is fed within the borders of the State by several important streams. On the north the Ckinakne River marks the boundary line between Stevens and Okanogan counties, and the Wenatschee River forms the northern boundary of Kittitass County. The Yakima passes entirely through the county so named from its source upon the eastern slope of Mount Tacoma.

West of the Cascade Range, from the foothills of the mountains to the ocean, the rainfall is the heaviest within the United States, ranging at the coast from 60 to 110 inches per annum. Irrigation is therefore unnecessary throughout the whole of western Washington, unless in some portions of the higher valleys of the Cascades. But little in detail is known of the higher portions, with their series of culminating peaks from Mount Baker in the north to Mount Adams in the south. The eastern surface of the Cascades will present longer valleys, less precipitous table lands, and a foothills and plains region somewhat similar in outline to that of the plains east of the Rockies. There are a number of important lakes in central Washington and on the eastern slopes of the dividing range. The largest of these bodies of water is known as Lake Chelan, in Okanogan County. There are a score more of considerable size which will probably be of value hereafter for storage basins for irrigation purposes. The valley lands of the Columbia are comparatively narrow so far as the water plane is concerned. The bench or mesa land seast of The Dalles are broader, possessed with fertile qualities, and presenting with moderate irrigation an immense area for wheat and other grains, alfalfa, vegetables, and smaller crops. It was estimated before the Senate Irrigation Committee in 1889 that in the central portion of the Columbia Valley, from Waterville southward to Ainsworth, at least 12,000,000 acres could be reclaimed for arable purposes, either by ditches on a large scale taken direct from the river by reservoirs with ditches attached or by storage basins to be filled by pumping from the river itself. The soil of the Columbia Valley is largely volcanic in character and possesses great fertility. The wheat-growing capacity of eastern Washington is regarded as inexhaustible, about 14,000,000 bushels being returned as the past year's harvest.

The climate of eastern Washington in its relations to agriculture must be counted as semi-arid in character. Westward from the line of Idaho to the Columbia River Valley, west and north, the annual precipitation shows a mean of about 17 inches; west of the Columbia River, from Kittitass south, the average will not exceed 10 inches. In the northern and central portions of Washington, including most of the counties of Stevens and Douglas and the whole of Okanogan, no systematic records have been made. The precipitation is probably a little less even than south of Kittitass. Taking the extreme eastern section along the Idaho line the annual mean precipitation is given as follows:

Counties.	Inches.	Counties.	Inches.
Colville and Fort Colville	16.50	Wallawalla	17.85
Spokane Falls, four years' average	19.82	Dayton	26.72
Colfax	25.31	Ellenburg (central Washington)	9.00
Pomeroy	20.32		

On the north side of the Columbia, in Klickitat County, the average will be about 12 inches. The difference in precipitation, as shown in the extreme eastern part of the State, is wholly a matter of altitude, the increase being about 3 inches for each 1,000 feet of elevation. The climate of both portions of eastern Washington is generally of a delightful character. The fogs of the coast region do not rise high enough to penetrate the river basins or cross the mountain line. In many respects the general features resemble those of central California; the nights are cool, the air clear in the daytime, and the sun is seldom overcast. The winter months will give a maximum temperature, south and north from Wallawalla to Spokane, of at least 60°. West and across central Washington the mean winter maximum will be about 50°. The summer average will range from 85° to 100°, the dryness of the atmosphere, however, making the noonday's sun quite tolerable. Snow falls in December on the mountain tops, and reaches the foothills and valleys by January, being usually gone in the early part of February. The "chinook" winds find their way through the Columbia gorge and play an important part in modifying and favorably affecting the climatic conditions of southeastern and eastern Washington.

What is known as eastern Washington proper occupies the area between the Columbia River and Cœur d'Aléne and Blue Mountains and British Columbia. This region is exceedingly fertile. The soil is composed of volcanic detritus and contains a large proportion of silicates. It is entirely sub-humid in character. Water for irrigation purposes may readily be stored in small basins and obtained from artesian or drainage wells, springs, or other underflow supplies. Taking the region from north to south the precipitation will be found in the valleys and lower bench lands to range at 18 inches, and in the upper valleys and cultivatable lower mountain slopes at about 24. Water is obtainable by means of bored wells at a depth of from 40 to 100 feet. The conditions in central Washington and along the great valley areas are such as to warrant belief in the ability of the settler to obtain an abundant local supply from drainage sources. Wells for stock purposes and domestic use, which may also be utilized to irrigate gardens and orchards will everywhere be readily bored and supplied with water. There are eight artesian flowing wells inside of the corporate limits of Pullman. They are 5-inch bore and discharge each from 700 to 1,000 gallons per minute. This water is obtained at a depth of from 75 feet to 95 feet.

From one of these wells the town is supplied for fire protection and use. The cost of boring is $4 a foot for rock and $1 for dirt. We go through a solid rock until the sandstone, in which is the water, is struck. In one of the wells, after the rock, a stratum of slate rock, then of coal, was struck, but the water flowed when in the slate rock. The water in one of the wells is strongly impregnated with iron and has medicinal properties; 25 feet from the surface is the highest the water would rise in any of these wells, carried up in pipes. All attempts to strike the flow outside of the town have failed.

The area reported under ditch in 1889 was 75,000 acres, of which 50,000 was in process of cultivation. In the Yakima Valley some 12,000 acres were being cultivated, 5,000 of which was in one farm, known as "The Moxey," belonging to a company of Eastern capitalists, which is maintained in a comparatively fine state of cultivation. It is estimated that in the valley of the Yakima alone 200,000 acres could be brought under cultivation by means of irrigation works at a comparatively small cost. It is further stated that with more extensive reservoirs and larger canals under proper engineering a million and a half of acres can be reclaimed within the hydrographic basin of the Yakima by means of the water supply thereof. In central Washington, the neighborhood of Ellensburg, in Kittitas County, is one of the finest valleys in the arid section. Some 22,000 acres of land were under cultivation in 1889. The increase for the past year will make this area about 25,000 acres. The waters which serve this area are brought successfully through a tunnel of considerable length made through the mountain range, on the slope of which Ellensburg stands. Ditch ownership in eastern Washington is, with but one exception, of a mutual character, the stock being taken by farmers whose lands are served by the waters which the ditch conveys.

Under irrigation the production given at various points in eastern Washington presents the following averages:

Product.	Quantity.	Product.	Quantity.
Wheat .... bushels..	35 to 40 45 to 50	Onions .... tons..	25
Barley .... do....	30	Cabbage .... do...	15
Oats .... do....	35 to 40	Carrots .... do. .	50
Potatoes .... do....	500	Beets .... do...	20 to 40

The larger yield of wheat given is that of the Walla Walla country, so also is that of vegetables stated. Fruit-growing in southeastern Washington is one of its most important industries. Some 1,200 acres, for example, are cultivated within a small radius of Walla Walla. Of fruit and vegetable products, the return per acre is estimated at $400. The yield and price per acre as given before the Senate committee were as follows:

	Selling price.	Total value per acre.
Grapes, 10 tons	$60 per ton..........	$600
Strawberries, 10,000 pounds	6 cents per pound....	600
Blackberries, 12,000 pounds	7 cents per pound	840
Raspberries, 5,000 pounds	7 cents per pound.....	350
Melons, 300 dozen	$1 per dozen	300
Tomatoes, 600 boxes	30 cents per box	180

On 613 acres of garden and fruit land the total for the year was $4,731. The total investment for purchasing and putting in operation is estimated at $3,600 and the cost of working per year at $1,500; the profit will therefore be nearly 100 per cent. The fruit marketed was raised by irrigation. It is claimed that while good crops can be raised in the semihumid section of Washington the secret of security and largest yields is found only in the proper storage and service of water.

The Northern Pacific Railroad Company have, it is understood, decided upon large investments for storage and irrigation works within what is known as the Big Bend of the Columbia. That river where it enters this region flows through a deep and narrow valley nearly or quite 1,500 feet above the general level. Below it enters a comparatively low and level plane. The land to be reclaimed is located within Lincoln and Douglas counties. Several million acres, it is estimated, will ultimately be placed under ditch. The climate of the region is considered equitable and is especially free from strong winds on account of its being encircled on the east and north by mountain ranges. The average rainfall will probably not exceed 14 inches. Streams are not frequent; several lakes are located in the section. Phreatic waters are found at a depth of from 4 feet in the draws and 40 feet in the lower foothills. The temperature in winter is like that of western North Carolina. Without irrigation wheat brings 25 bushels to the acre; corn also produces well for no large demand; barley averages 55 bushels, oats 60 to 70. With irrigation this average it is claimed can be largely increased. As a stock country it is regarded as the best on the continent.

Great activity is reported for the past year at North Yakima and in the adjacent region. The Yakima County Irrigation Company, organized late in 1888, now has under ditch an area of 30,000 acres. The original settlement of six families has increased to fifty. Land valued at $2.50 per acre before settlement is now held at from $30 to $50 with water. The sources of the water supply in this county are the Yakima and Columbia rivers. Farms range in size from 40 to 150 acres. Landowners also purchase an inalienable right to the water. They are holders of stock in the ditch. The duty of water is 1 miner's inch per acre. The railroad irrigation works proposed in this region, which have been surveyed during the past year will, it is expected, serve 500,000 acres. The canal length will be 100 miles. The Selah Valley Ditch Company organized in 1888 was surveyed and constructed to serve 15,000 acres of land, which are now under ditch. The source of supply is the Naches River, the water of which is conveyed by ditch and flume to the land. Irrigated land before the construction of ditches is valued at $2 per acre. Its present value with water is estimated at $40; without water, at $5. The duty of water is but one-half miner's inch per acre. Farm holdings average 80 acres each. The Fowler Ditch Company was organized in the spring of 1889 to serve 6,000 acres. The source of supply is the Yakima River. The crops raised are fruits, wheat, oats, potatoes, alfalfa, vegetables, hops, and grasses. The yield is estimated at 50 per cent more than on nonirrigated land, however favorably the latter are situated for natural subirrigation.

Recent reports from Kittitas County, another important center of irrigation works, give encouraging accounts of progress within the past year. At Ellensburg the Westside Irrigating Company, the latest corporation in operation, was organized in June, 1889. The stock is owned by about 40 farmers, and the land served covers an area of 10,000 acres. Before irrigation land was worth $1.25 per acre; with water supply it ranges from $25 to $150 per acre. The sources of supply are the Yakima River, the Tanems and Manastash creeks. The works consist of a ditch 14 miles in length with a grade of 20 inches per mile, and with the estimated capacity of 3,000 miner's inches, or 4,500 cubic feet per minute. The duty of water is estimated at one-half inch per acre. A permanent water right costs $30 an acre and the water belongs to the stockholders. Under State law in Washington water is public property to be used for beneficial purposes. Prior appropriation alone gives title, and for some purposes the right may be transferred. Crops without irrigation are, as a rule, failures. Farm holdings run from 160 to 320 acres. The general price of irrigated land under ditch will be about $60 per acre. The average duty of water in the county is 1 miner's inch per acre per second. Wheat on irrigated land returns 60 bushels per acre, barley 50, oats 50, and other crops in the same proportion. The Watts Ditch Company have 140 acres under ditch. The Manastash Water Ditch Company, organized in 1872, serves an area of 1,500 acres. The works are an open ditch and short flumes for small laterals. The duty of the water is 1 miner's inch per acre.

Mr. Kirk Whited, of Wenatchee, writes as follows in relation to irrigation in Kittitas County:

> Through this part of the country the Columbia River flows in a deep channel from 30 to 70 feet below its immediate banks. In many places the mountains rise abruptly from the river, while in other places there are valleys of various widths up to three miles. The soil in these valleys is rich, but requires irrigation to be productive.
>
> On the east and south of the Columbia is a rolling plateau from 1,500 to 2,500 feet above the river, and only small streams come in from that side. On a strip of this Big Bend plateau about 25 miles wide following the course of the river, the rainfall is sufficient to produce grain without irrigation, but the valley below is dry and hot in the summer. On the west and north side of the Columbia the country is principally mountainous, with fertile valleys, some of them containing several thousand acres; the streams are more abundant and the waters in many cases are being utilized for irrigation.
>
> On the west side of the Columbia River the Quiltoechiro and Stemilt creeks and several small streams coming out of cañons furnish about one-fourth enough water for the valley; there are two or three associations of settlers and several individuals who have taken ditches. If plenty water were supplied to the main valley, that which is now taken from the two creeks could be profitably used on higher lands.
>
> The Wenatchee River is about 400 feet wide, 3 feet deep, and has a fall of 13 feet per mile in the lower part of its course, and runs in a deep channel much below the surface of the valley. A preliminary survey for a ditch was made last spring. The line proposed lies on the south side of the Wenatchee, and starts about 25 miles above its mouth. The broken nature of the country will make such a project very expensive and at present, at least, impracticable.
>
> A ditch to irrigate that part of the valley lying north of the Wenatchee is believed to be practicable, and steps are being taken with that end in view.
>
> East of the Columbia is a tract of 15,000 acres (shown on the map) lying on two benches that would be very productive land for fruit and other crops if supplied with water, but there are no streams and only one or two small springs on the whole tract, and the Columbia having a fall of only 2 or 3 feet per mile it is impossible to take a ditch from that river. The Columbia River at this point is 550 feet above the sea level, the climate in summer is dry and warm, the winters are mild, so that all the fruits and vegetables of the southern United States thrive to perfection.
>
> As the Columbia River flows in a deep valley between a high plateau on the east and the Cascade Mountains on the west, it is believed by many that flowing water can be obtained by boring artesian wells near the foot of the hills, and that this is a favorable place for the experiment. If it should prove a success here, others would be sunk in many places along the river.

In the extreme southeastern section of Washington—that is, Asotin County—there are a number of small farm ditches in use for the supply of the farms. The mileage or acreage is not given, but the extent is yet small. On the Idaho side of the Snake River, however, by which this county is watered, a considerable use of the river is made by means of lifting through steam pumps and distributing water thereby on valuable orchard lands. Throughout this section of Washington no large works are reported. Many large springs on the north side of the Columbia River are used for garden and fruit purposes. The cost of the plant employed is generally $100,000, which serves from 2 to 40 acres. These small works extend along an area of 120 miles. Nonirrigated lands of this character will sell from $2 to $10 per acre; with springs and wells that can be used for fruit and garden irrigation, sell at from $75 to $100 per acre. In Whitman County, where Pullman is situated, water is seldom used except to irrigate small farms and fruit areas, but increasing interest is being manifested in the advantages to be derived in the storage and use, at proper periods, of the waste water of the wells for fruit cultivation. In Franklin County no canals outside of individual farms are reported. Some small ditches are in use. At Pasco the use of well water for irrigation purposes has begun. The water is lifted by means of steam pumps, serving some 60 acres at a cost of $12,000. This was set in operation during the past year, and no results have as yet been achieved. Farm wells are dug and bored, reaching water at a depth of from 10 to 125 feet below the surface. The power used for lifting is generally that of windmills and horse power. Under the recent law adopted by the State legislature, an irrigation district has been formed in Franklin County embracing 19,500 acres. It is proposed to lift the water 115 feet by steam pumps from the Columbia River. The volume will be 20,000 gallons per minute, which will then be distributed by canals over the land to be served. In Walla Walla the irrigation system is entirely with small farm ditches; no corporate or associate efforts exists therein. The underflow of water in this county is near the surface and quite abundant. Wells are generally sunk and water is raised by means of windmills and other mechanical power. Well water and springs are commonly used for orchard and garden irrigation.

The following statements are compiled from data sent to this office in reply to circulars, or are gathered from other credible and authenticated sources:

On the west side of the Walla Walla River an enterprise of considerable magnitude is in progress. Surveys were made late in 1891 for canals to be constructed on both sides of the river, but no other report has yet reached this office. The Walla Walla country is one most favorable for the raising of fine fruits and vegetables. It is also almost the center of one of the greatest wheat-growing sections of the United States. This is not an arid section, but must be classed as sub-humid in character; the storage and distribution being valuable for the purpose of security in farming operations.

The canal of the Northern Pacific, North Yakima, and Kittitas Irrigation Company takes water from the Yakima River some 10 miles below North Yakima. The head works consist of a low concrete dam with butterfly weirs arranged to fall at high water and divert some 450 cubic feet of water per second into the company's canal at all times when irrigating may be in progress. The canal is designed to be about 60 miles long, and about 30 miles are actually being built. The cross section is 30 feet at the bottom, slopes 2 to 1 inside, 1½ to 1 outside, berm 6 feet wide, bank 8 feet high. All excavated material is used to strengthen the banks and none is wasted. The cut is 20 per cent of fill. The grade is 3 feet in 1,000, and the estimated depth of water is 6 feet. The material passed through is generally a fine volcanic soil, exceedingly rich when watered, but so fine and dusty as to be very difficult to handle. The lateral system for this canal has not yet begun. It has been proposed to introduce wrought iron pipe, as the slope of the land from the canal towards the Yakima River is in many places too steep for the economical use of ditches.

The 65 miles of canal are designed to cover 60,000 acres. A second canal, of the same section but of greater length, is proposed to water another 60,000 acres lying above the present work. This second or "High Line Canal," if built, must cross the Yakima River in an inverted siphon, after passing through several miles of flume. In connection with this canal will be a series of natural storage reservoirs, supplemented by timber-crib dams in the headwaters of the Yakima and Nachess Rivers. The most novel scheme for Eastern Washington is that of the Yakima Land Company, embracing 10,000 acres of the upper Moxee Valley. In November, 1890, an expert report on the probability of finding artesian water in a country believed to be volcanic in its formation was obtained. The report was favorable and work begun at once. One well was sunk during 1891 into a stratum of water-bearing sandstone, and it yields through a 6-inch pipe a flow of 1.13 cubic foot per second. A second well, 10 inches in diameter, is believed to be entering the same stratum. This discovery of water-bearing sandstone in the high lands of eastern Washington, with its attendant circumstances of freedom from malaria and typhoid fever, is one of the greatest advances made in the last few years in that rapidly growing State.

The farmers of the Cowchee and Wide Hollow valleys have organized an irrigation district, under recent State law, similar in character to the California system. The Selah Ditch Company are again active, and their service, if completed, will assist a very fertile tract. Another enterprise proposes the reclamation of 15,000 acres along the Columbia River and within Yakima County. Interest in irrigation is steadily increasing.

The views of a prominent business man interested in a large irrigation project in Yakima County, Wash., are presented as illustrative of what organizers and administrators claim to be an error in our land laws. To a special agent of the Department and this office, Mr. R. K. Nichols, the mayor of North Yakima, said:

> One of the evils which irrigation schemes have to contend with is the persistent blackmailing to which they are exposed from "squatters." This in many instances amounts to a practical obstruction of irrigation development. While it is true that the Government grants the right of way to canals and ditches for irrigation over and through its lands, yet the class of persons who follow along behind the surveyors in running the preliminary lines of irrigation companies, and as soon as they can ascertain from the stakes the necessary localities which the irrigators must secure for their canals or works, they at once file upon them and commence settlement, in order to compel the promoters of the enterprise to buy them out or else resort to the tardy method of "condemnation." This is a crying evil, and has been carried to such an extent as in many instances to drive off weak companies, who otherwise would have proceeded and opened up large and valuable tracts of arid lands to settlement and cultivation.

This is entirely from the corporation point of view, however.

Mr. Nichols recommends Congressional enactment, so that whenever an individual or company engaged in promoting irrigation enterprises shall project its lines over a tract of Government lands for its canals from the source of supply to the place or places of intended use, and shall file a diagram of this line of canal in the office of the nearest United States district land office, that such filing of the plat by the individual or company shall, *ipso facto* give him, it, or them, an indefeasible right as against every one but the Government, for all the necessary ground for a right of way along the line of their canal or ditch, not to exceed

200 feet on either side of the center line of such canal or ditch, the same to become a vested right as soon as satisfactory proof is made at such district land office of the completion of the works, and patent issue therefor.

He also observed that in the arid lands of the State of Washington, the rainfall is practically nothing, that water for irrigation has to be brought from the mountains where the precipitation of moisture is very great. That in the spring of the year the streams leading from these mountains carries a superabundant supply of water for all purposes; but that owing to their high grade along in the summer, they are drained off, and some years dwindle away to almost nothing. This difficulty, he stated, can be easily cured and an ample supply of water maintained for all seasons of the year by irrigation companies adopting a systematic system of storage reservoirs in the lakes, valleys, and cañons of these mountains; but that here again they are continually blocked by the "black-mail" scourge.

Engineers have satisfied themselves by actual measurement that there is not sufficient water at all seasons, in their source of supply, the Yakima River, for the wants of their canals and the requirements of the riparian owners; that they must provide reservoirs for the storage of the surplus water of the spring and early summer; therefore they proceeded up into the mountains, in and about the glaciers, and filed notices of appropriation of dam sites at the outlets of some mountain lakes, which had hitherto been valuable only as watering places for the wild beasts of the forests. Instantly, the margins of these lakes, high up in the mountains, having frost every month in the year, were found to possess wonderful agricultural properties, were settled upon and claimed by squatters, who will doubtless all in time present heavy claims for damages for flooding these valuable lands. Mr. Nichols insisted that if the Government desires these arid lands to be reclaimed and populated, made remunerative and productive, something should be done, and at once, to remove this difficulty.

Mr. Nichols suggested that an association on obtaining a certificate, signed by the governor and secretary of state of any State or Territory, declaring that such association or corporation was actively and actually engaged in the construction and maintenance of irrigation works in such State or Territory, and should, with such certificate, file a map showing the line of their works and proposed works in the office of the nearest United States district land office, and that if on such plan it should appear that certain lakes, valleys, ravines, or cañons were necessary as reservoirs for the storage of water from their sources of supply; that thereupon, by published notice from such land office, the reservoir sites delineated on such maps should be withdrawn from entry or settlement, and that upon the completion of the works of such irrigation, satisfactory proof being made thereof to such district land office, a survey at the expense of the irrigation company should at once be ordered and made and a patent issue therefor to the irrigation company, including the requisite land at the outlet for the necessary dams and works. Such a law should also, Mr. Nichols observed, be hedged about so as to sufficiently protect the Government from land grabbers and speculators.

In the Yakima Valley there are very many farmers who have already procured title from the United States and who are offering the half of their holdings as gifts to secure complete irrigation for the remainder. "Surely," he added, "if the American farmer can afford to do this to encourage the development of this wonderful sage-brush land, the Government ought to do something."

Why [he went on to say], there are tens upon tens of thousands of acres of sage brush where a jack-rabbit will starve; but fertilized with the necessary water, will produce in abundance anything which can be grown in this latitude; support a husbandman and his family on every twenty acres, and prosperity, peace, and happiness will reign where now only desert solitude obtains. Certainly [he added] it seems to me that it would only be wise business economy for the Government to allow the constructors of large irrigation works, the right for a certain length of time after the construction of their works of purchasing a certain portion of the Government lands under the waters of their canals, at a stated figure, say $2 or $2.50 per acre; and that these lands should be withdrawn from the market on filing the map of location of the canal, something after the manner indicated before by him, respective to rights of way and the establishment of reservoirs. * * *

In his opinion, such an act would be a great encouragement, and would energize the cause of irrigating the Government's barren wastes immensely; that as matters now stood, in view of the great cost and risk of the investment, all irrigation companies must possess great financial ability in order to accomplish anything.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers received to circulars sent by this office:

DOUGLAS COUNTY.

Waterville (post-office), P. E. Berry (September 28, 1891):

"No irrigation in the county. Limited flat along Columbia River could be reclaimed by irrigation, but at very great expenditure, as water would have to be conducted from the rivers for a long distance, over much rough land in order to reach the upper flats. (Above the 'river flats' is the prairie or plateau country.) The soil of the river flats is well adapted to fruit-raising. The county is mainly productive of small grain and cattle-raising."

YAKIMA COUNTY.

North Yakima (post-office), R. Strobach (September 26, 1891):

[Surveys, etc., have been made for an irrigation system which will take its water-supply from Tietan River, proposed length about 35 miles; main ditch will carry 350 cubic feet per second, before laterals are taken out; other works, one head-gate, 10 miles of flume. Cost per mile of ditches, etc., flume about $20,000; dirt and rock, from $5,000 to $6,000. Area under this system, 39,380 acres first-rate lands and 6,000 acres third rate, and cost of water per acre not to exceed 75 cents.]

Average cost per acre in this vicinity for preparing land for cultivation under irrigation, about $10 (under the district undertaking it will cost $10 for water alone on account of engineering difficulties.)

Average cost per acre of irrigation works, ditches, etc.: On small streams with great fall, from $2 to $5; on rivers, from $5 to $15; cost for annual maintenance and repairs merely nominal as yet.

Area under ditch in neighborhood, perhaps 100,000 acres; under cultivation, about 5,000 acres. (When present undertakings are carried out area will be increased to 250,000 acres.

Products: Hops, alfalfa, and fruit.

Average value per acre: Hops last year at 35 cents, earned from $350 to $500; alfalfa, from $40 to $75; fruit, from $150 to $200.

North Yakima (post-office), J. G. Lawrence (September 19, 1891):

Water supply for irrigation from streams fed by the mountain snows; supply abundant, except some years on smaller streams. "The principal portion of the land capable of irrigation by our streams is yet untouched. Artesian supply, also in great quantity, has been obtained within the last few months."

Irrigation works: Nine ditches, 12 feet each at bottom, 16 feet at top; about 100 miles of same; 1 ditch, 15 feet on bottom, 20 feet top, about 20 miles; 1 ditch, 30 feet on bottom, 60 feet on top, about 18 miles, to be extended to 90 miles. The only reservoirs as yet are lakes in the mountains (with dams of various sizes), covering an area of about 15 acres. There are also about 50 irrigation steam pumps, about 50 wheels, and a few wind pumps.

Cost per mile of ditches, etc.: Neighborhood ditches, about $50; larger ditches, from $500 to $1,000.

Average cost per acre of works, ditches, etc.: In lower valleys about 50 cents; in higher valleys, about $2. Upon the still higher or uplands ditches are now being taken out for the first time at an average cost of about $4 per acre.

Average cost per acre for annual maintenance and repairs: For smaller or farm ditches, about 10 cents; for larger or corporation ditches, from 50 cents to $1.

Average cost per acre for preparing land for cultivation under irrigation for clearing sage brush, $2; plowing, $3; total, $5.

Cost of water supply to user per acre, 50 cents.

Area under ditch, about 150,000 acres; under cultivation, 50,000 acres.

Chief products: Wheat, oats, barley, alfalfa, timothy, clover, hops, potatoes, tomatoes, turnips, cabbage, etc., apples, apricots, cherries, prunes, plums, peaches, pears, watermelons, and berries of all kinds in paying quantities.

Average yield of products per acre: Wheat, 40 bushels; barley, 40 bushels; oats, 50 bushels; hops, from three-fourths to 1 ton; alfalfa, 5 tons; timothy, 2 tons; clover, 5 tons; potatoes, 500 bushels; tomatoes, 5 tons; cabbage, 18 tons; turnips, heavy yield; watermelons, 175 dozen; all fruits yield well.

From different sources it is learned that three artesian-well bores have been made, two of which are entirely successful, having, it is stated, a 6-inch flow, and under such pressure as to be sufficient for the irrigation of 160 acres.

A large number of well bores have been contracted for in the Upper Moxee Valley, and one special enterprise on the high mesa land is looked forward to with great interest. For one of these wells $3,500 has been raised, so that the full limit of depth, flow, and pressure may be obtained.

The North Pacific Canal Company have completed 25 miles, and expect to finish 20 miles before the summer of 1892.

WYOMING.

As one of the northwestern groups of States, Wyoming forms part of the sources of the greatest river system on the continent. It lies between latitude 41 and 45 degrees north and longitude 104 and 110 degrees west. It is about 420 miles from east to west, and 300 miles from north to south. In area it is the fourth largest State in the Union, and contains 62,645,120 acres. On the north it is bounded by Montana; on the east, by South Dakota and Nebraska; on the west, by Idaho, and Montana; and on the south, by Colorado and Utah. It is divided by vast parallel chains, from which rise high peaks, culminating, in the case of the Laramie, at the height of 10,000 feet above sea level. Wyoming, topographically and hydrographically, is a great water-gathering area; remarkable alike for the extent of its high altitude precipitation, conveying great volumes of water through its river courses, and bearing remarkably striking relations in its eastern half to the climatology of the great plains region. The mean altitude is 6,450 feet. The main range of the Rocky Mountains extends across it southeast to northwest, entering Colorado along the one hundred and fifth meridian of longitude. The larger portion of the new State lies northeast of the continental divide. From the eastern border to the western slope of the continental range, Wyoming consists of a succession of parallel mountain ranges, separated by broad valleys and having the normal Rocky Mountain trend towards the northwest. The average elevation of the intra-mountain valleys ranges from 4,000 feet to 6,000 feet. The mountain ranges rise from 8,000 to 11,000 feet. The principal of these ranges are the Wind River Mountains, in the northwest, which is one of the sources of the Rio Colorado; the Black Hills, in the northeast; the Laramie Range, in the southwest; and further to the south the Medicine Bow Mountain, lying on the Colorado border and entering that State; further west and beyond the main Rockies are the Bishop Mountains; the Rattlesnake and Sweet Water Ranges in the central and western part of the State.

The Rattlesnake Hills are north of the Sweet Water, the mountains of the same name being pierced by the river. The culminating features of the topography of Wyoming, outside of its mountain peaks, are the Laramie Plains, which have a length, northwest by southeast, of 90 miles, and an average breadth of 75 miles, with an elevation of 7,000 feet, and embrace an area of 4,480,000 acres. The surface of this plateau varies in character and somewhat in elevation, a considerable portion of the area consisting of grassy plains, while another section is formed of ragged foothills with but little vegetation. The Black Hills, a large portion of which are in South Dakota, lie between the forty-third and forty-fifth parallels of latitude and the one hundred and third and one hundred and fifth meridians of longitude. They extend north and south about 100 miles, and average about 50 miles in breadth.

West of the Rocky Mountains the Green River section bears the characteristics of the basin region, of which Utah and Nevada form the principal political divisions. Hydrographically, it is the chief northern tributary of the Colorado River system. Topographically, it presents a broad series of table lands covered with sage brush (artemesia) and gramma grass. The Green River Valley is of a more arid character than the great mountain valleys that lie east of the continental range. This basin extends from latitude 43° southward to the Uinta Mountains in Utah, and from the Wind River ranges westward to that of Wyoming. Its area in Montana and Utah will embrace about 6,500,000 acres. The soil is of a gravelly, granitic character, and with the application of water will be found remarkably fertile, producing the temperate fruits and grain in abundance.

East of the continental divide, Wyoming is drained by large tributaries of the Missouri River. The Big Horn (which in its upper course is known as the Wind River), the Tongue, and Powder rivers also rise in the Rocky Mountain ranges and flow north and join the Yellowstone in Montana. These streams all have important tributaries. In the northeast the Little Missouri flow northward, passing through the southeast corner of Montana and joining the Missouri in South Dakota. Further south are a number of its forks. The Cheyenne River flows eastwardly into the Dakotas. The South Platte, still further south, rises in the northern part of Colorado and flows directly northward into Wyoming, where it receives the Medicine Bow River and the Sweet Water—one from the east and the other from the west—and then bends east and southeast, just below the center of the State, until it enters Nebraska, near the boundary of which it receives the Laramie River, with its tributary from the south and Raw Hide Creek from the north. In the southeast corner of the State several small streams rise and join the South Platte in Colorado. The high altitude at which all these streams rise insures their almost constant character. It indicates also the possibility of an enormous increase for economic purposes of the volume of water which, with melting snows and heavy rainfall, they will, under climatic conditions, carry direct to the main rivers and hence to the Gulf. The storage of torrential or storm waters and the recovery to the surface of a great percentage lost by rapid drainage and seepage into the earth will be found in Wyoming a task simple to competent engineering, the results of which will amply repay the efforts made. The surface supply furnishes water enough even now to irrigate from 18 to 20 per cent of its entire area. Appropriations have already been made from nearly 600 streams, and for farming and grazing purposes a large supply has been taken out by irrigation ditches. The water shed of Wyoming is equal to fully one-third of the entire State, that is, over 22,000,000 acres. The character of this hypsometric area may be better understood by the following table of altitude:

Area between—	Square miles.
3,000 and 4,000 feet	3, 000
4,000 and 5,000 feet	19, 000
5,000 and 6,000 feet	20, 000
6,000 and 7,000 feet	24, 000
7,000 and 8,000 feet	17, 000
8,000 and 9,000 feet	7, 200
9,000 and 10,000 feet	4, 300
10,000 and 11,000 feet	2, 300
11,000 and 12,000 feet	900
12,000 and 13,000 feet	100
Total	97, 800

There are no large lakes, but many small ones, lying in the mountain regions. A majority of these are so situated as to be readily made serviceable for storage reservoirs. The Yellowstone, within the boundaries of the National Park, so named, is a fine sheet of water from 10 to 15 miles wide, 22 miles in length, and having a depth of 300 feet. Upon the divide, on either side of this lake, are many small lakes at from 10,000 to 11,000 feet above sea level. The majority of these small lakes have no outlets, showing that they are only storage places for drainage of the plateau region. Southwest of the Yellowstone Lake are found the Shoshong, Madison, and Lewis lakes, with others still smaller and mostly unnamed. The National Park, in the north corner of Wyoming, must prove in the development of irrigation hydrography one of the most fortunate acts of national legislation, reserving as it does to future industry those sources of a great drainage system flowing east and west that are found within its borders. For example, 12 miles south of the Yellowstone Lake lies one of the principal sources of the Snake River, known as Heart Lake.

Forty miles from the source of the Snake, Jackson's Lake is found, an irregular body of water 8 miles in length and from 2 to 3 miles wide with a depth of 250 feet. Some distance below, two other lakes about a mile apart are found. Still farther to the south are two bodies of water called Taggart and Phelps Lakes, which are nearly surrounded by moraines or glacial walls, having a height of 150 to 420 feet above the surface of the waters. In the Teton Mountains, at an altitude of 10,300 feet above sea level, a lake bed filled with solid ice has been found. Fremont Lake, 10 miles long and 2½ miles wide, lies about 12 miles from the southwest of Fremont Peak. In the Bear River region, near the source of Salt River, may be found a beautiful body of water called Alice Lake. There are a large number of such lakelets in Wyoming, a great many of which will yet be utilized in a storage system. The average annual temperature of the State reaches the mean of 44° The entire State lies on the isothermal line of 50°. In the mountain ranges the mean annual temperature will average as low as 36°, while eastward; on the plateaus and plains, its average is from 44° to 46°. The records at Cheyenne, covering for temperature a period of fifteen years, shows an annual mean of 43° 56′, a minimum of 25°, and a maximum of 90° 2′. The average of humidity would be about 54°. A notable fact is that the prevailing winds for eleven out of fifteen years have been from the north, during the other four they came from the west. This is of great importance in considering the channels of distribution or precipitation over the great plains.

West of the continental divide the valleys of the Big Horn, Sweet Water, and other Missouri River tributaries, form the chief arteries for distribution of such Pacific Ocean currents as they cross the Cascade and Upper Rocky Mountains on their way from the North Pacific. Their annual mean is a little higher. The greatest humidity in Wyoming, so far as rainfall is concerned, will be found in the four months of summer—that is, from May to August—when evaporation is also most rapid. Owing to the heavy snowfall the actual humidity of the atmosphere is greater from the middle of August to the middle of spring. The general climate is equable, high, dry, and quite mild. Though the temperature in midsummer will reach 90°, the nights are always cool. In midwinter, though it may fall below zero, the dryness of the air makes it far more endurable than the higher temperature along the humid Atlantic coast or in the great river valleys. It is very difficult to estimate or arrive at anything like a satisfactory conclusion as to the amount of water precipitated, in the form of snow, upon the mountain ranges of the State. State Engineer Mead considers it a fair estimate to state that the annual depth in water, chiefly of melted snow, must be between two and three feet, giving an approximate deposit of 60,000,000 acre-feet of water. Allowing for the disappearance of two-thirds of this supply by evaporation and phreatic processes, there will still be left 20,000,000 acre-feet of water to pass down the streams and be made valuable for irrigation purposes.

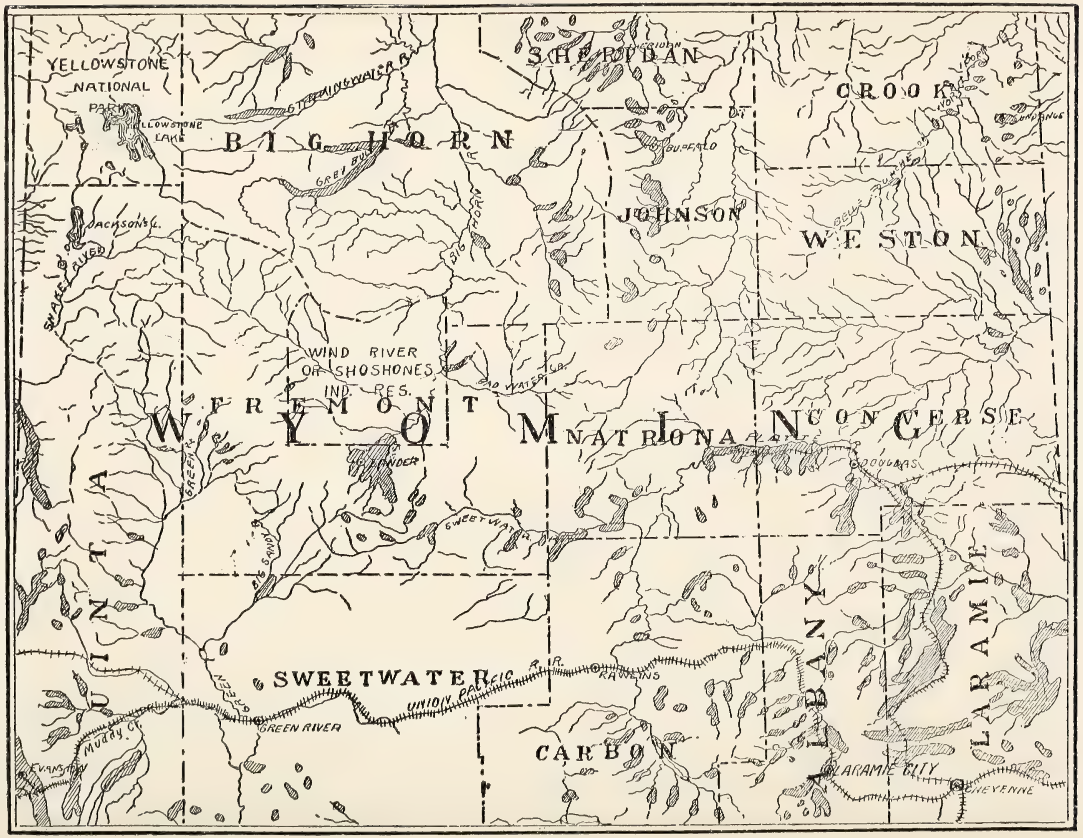
The forests of Wyoming, variously estimated at from 7,000,000 to 15,000,000 acres, can give, except at the sources of the streams, but a slight influence upon either the retention in the soil or distribution by channels, of the great precipitation that falls within this State. An estimate by counties, embracing also the Yellowstone Park, which is more heavily timbered than other sections, will give an area of 7,718,400 acres. The larger portion of the timbered area is confined to the mountain ranges, between 4,500 to 10,000 feet above sea level, and is formed on the eastern slopes of the continental range.

The surface of the valley, bench, and plateau lands of Wyoming is usually slightly rolling in character, quite free from stones, bowlders, or other obstructions, easily accessible, and readily broken to the plow. The valley soils are a black loam and red gypsum. The mesa or bench lands are largely of a rich, red, sandy loam. The great expanse of alkilized surface, covered only by sage brush and greasewood, can be made by irrigation among the most fertile of areas. The larger proportion of Wyoming will doubtless continue to be devoted to stock-raising. Its grasses are among the most succulent and valuable to be found in the region west of the one hundredth meridian. The climatic conditions and the distribution of its waters make exceedingly favorable conditions, not only for ranching on a large scale, but also for the breeding of and caring for fine cattle and horses. A large proportion of the extensive appropriation for water is now intended for use on the cattle ranches. As irrigation develops the water will be first applied to the cultivation of alfalfa and other forage crops, thereby increasing the capacity of the land for pastoral purposes, lessening in all probability the area of ranches and rapidly increasing the change already begun from cattle ranching to stock and breeding farms of a high character. A considerable proportion of the highest plateau region of Wyoming will raise, with the storage development and judicious distribution of water, large crops not of forage alone, but of the hardier grains, vegetables, and roots for the supply of both man and animal. In the eastern, and especially in the northeastern portion of the State, the agricultural area is already known to be extensive while new arable districts are constantly being brought to public notice.

This northeastern district, including Johnson, Sheridan, and Crook counties, is the best watered in State, all of the counties being supplied with mountain streams whose waters have great fertilizing qualities. Johnson County now consumes, it is claimed, one-fourth of its surface supply, and 64,000 acres are given as capable of easy irrigation. There were recorded 430 ditches in the county clerk's office in 1889, with a total length of 730 miles. The total capacity is stated at 9,117 cubic feet per second. The number of ditches already constructed in Johnson and the adjoining county of Sheridan will successfully irrigate, it is claimed, 450,000 acres. The products of these 3 counties include all the tame grasses and grains of the temperate region. Wheat and oats return 45 to 50 bushels per acre; potatoes, 200 bushels; onions, 300 to 500 bushels. The area embraced within the counties of Johnson, Sheridan, and Crook are watered by the tributaries of the Missouri River, which flow through them northward to that great channel. Carbon County, to the southward and center, with an area of 12,816 square miles, is another large farming region. Irrigation to insure crops is an absolute necessity. The county is watered by the Sweetwater and Platte Rivers. In 1889 21,000 acres were under fence, and during the succeeding year this area was increased by at least one-third. The whole of the Platte Valley within this county, from 10 to 30 miles wide, is available for agriculture, and readily yields large crops of the hardier cereals. Oats return 46 bushels, wheat 50, potatoes 3 tons, beets 4 tons, and hay 1,600 tons per acre. There are no large irrigation ditch systems in Carbon ; appropriations of water are distributed through private ditches. Nearly all the land under fence is supplied by water from ditches. About 50,000 more acres can, it is claimed, be irrigated from the surface supply. Converse County, also part of the North Platte Basin, is devoted generally to stock-raising, but has about 8,000 acres under cultivation, 3,000 of which are irrigated. As elsewhere, the mesa or bench lands, when supplied with water, are found to be best for farming purposes. Without irrigation the small farms will give 30 to 40 bushels of wheat per acre; irrigated, the increase will be from 50 to 75 bushels per acre. Alfalfa produces 2 full crops per year. Albany County, which covers the high Laramie Plains, is found to be possessed of fertile soil, well adapted to temperate cereals and grasses, accessible to irrigation,and with water sufficient for two-thirds of the whole county. The mountain portion is heavily timbered, and root crops grow in great abundance. There are about 25 ditches, having a main length of 200 miles and in laterals nearly 1,000 miles. This system includes 6 small reservoirs. The cost has been about $250,000. The acreage served is over 100,000. The altitude ranges from 5,000 to 7,000 feet. Fremont County has also a considerable area cultivated, and claims one-half of its entire area as suitable for farming purposes, especially those acres that have been irrigated.

No failure of crops is known when the land is watered. These counties, with those of Uinta and Sweetwater, include nearly all the areas now cultivated within the State of Wyoming. It is claimed by the State engineer's office that at least 5,000,000 acres of land in Wyoming can be made productive by ordinary irrigation methods from the waters now in sight. This area, it is estimated, could easily be doubled by the construction of reservoirs for the storage of storm waters. No consideration has, as yet, been given to the supplies to be found below the surface, in the form of undersheet water in the great valleys, or of the underflow in the lower bench and prairie lands, formed from the drainage of the adjacent foothills and ranges. Artesian water, it is known, can be obtained in considerable quantities, but as yet it is not to be considered a source of supply for such economic purposes as irrigation. The soil, wherever irrigated, is found to be fertile and productive of all the hardier grains, vegetables, and fruits growing elsewhere in the temperate zone. The average yield of wheat will not be less than 25 bushels per acre; oats will produce 30 bushels. At $1 for wheat and 50 cents for oats, the value of such crops would not be less than $175,000,000. The yield per acre in potatoes will not be less than 150 bushels; while grass crops will produce from 5 to 6 tons per acre.

According to the State engineer's report for 1889, there were recorded over 2,600 ditches, drawing their supply from more than 400 different water courses. With irrigation scarcely established there is enough land under ditch and ready for the plow to make 80-acre farms to the number of 20,000. The best watered and most extensive agricultural districts are found in the central and northeastern portions of the Territory.



Irrigation Map of Wyoming.

Shaded portions show districts now under ditch.

The number of recorded ditches is over 2,600, and there are more than 5,000 unrecorded. The total length of irrigating ditches is over 5,000 miles. Wyoming, then, is third in the total area of its irrigated land and second in the number and mileage of its irrigation canals. It must be remembered, however, that it is the largest for pastoral purposes and cultivation of forage. The following table was filed with the Senate Committee on Irrigation in 1889:

[Territorial engineer's report.]

Number of districts organized	9 *7
Total number of ditches recorded	2,438
Total mileage of ditches as reported	4,250
Acreage under water	1,946,875
Total capacity claimed in cubic feet of water	20,381,723

[According to the U. S. Geological Survey as presented by Director Powell.]

Acres under ditch constructed or projected	1,227,819
Acres irrigated or under water	500,000
Percentage actually irrigated	.08
Acres cultivated as per this ratio	40,000

The chief sources of this irrigation supply, as stated by counties, are as follows:

Counties.	Streams.
Albany	Big and Little Laramie, with their tributaries.
Carbon	Sweetwater and North Platte and branches.
Fremont	Green, Snake, Yellowstone, and Sweetwater rivers, the Big and Little Horn, Beaver, Gray, Bull, and other tributaries.
Converse	North Platte and Cheyenne Rivers, with numerous tributaries of both.
Crook	Powder, Little Missouri, Belle Fourche, Upper Cheyenne, Little Powder, and many tributaries; also Sand Creek, fed by large mountain springs.
Sheridan	Upper tributaries of the Tongue, Little Horn and Big Horn rivers.
Johnson	Powder River and its larger forks.
Uinta	Bear, Green, Salt, and Snake rivers, with forks and tributaries.
Sweetwater	Green River, Big and Little Sandy, and tributaries thereof.

The reservoir works so far constructed in Wyoming are designed entirely for general supply. The facts relating to them are as follows:

Location.	Source of water supply.	Capacity of reservoir.	Cost.
Cheyenne, Laramie County	Infiltration wells in bed rock of Crow Creek by gravity.	Dam and reservoir, 214,000,000 gallons.	$275,000
Laramie City, Albany County	Springs 2½ miles east of city.	Area of 5 acres	18,000
Rock Springs, Sweetwater County.	Green River	3,000,000 gallons	200,000
Sundance, Crook County	Springs, by gravity, to and from reservoir,	60,000 gallons	13,000

In addition to these works there are 18 artesian wells in the Territory, 16 of them being located at and near Laramie City, 1 at Cheyenne, and 1 at Rollins. The Laramie wells are from 130 to 150 feet deep. There are also a small number of bored wells in the neighborhood of Laramie, in which the water rises not quite to the surface and is raised by means of windmills. The water of these wells is used entirely for domestic and stock purposes. Prof. Bailey, who served as field geologist in the artesian wells investigation during the summer of 1890, for southeast Dakota and eastern Wyoming, finds all the con-

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*Unorganized. The largest portion of these acres is cultivated for forage, not grain or vegetables.

ditions necessary for a large artesian water basin. The report of the artesian wells investigation gives his observations and statements, which include sixty salt and gas wells, artesian in character. There is no doubt whatever that large supplies of phreatic waters may be obtained at small cost within the valleys and lower basin regions of Wyoming. The existence of seepage water on the lower portion of plains belonging to the Laramie Range has already been developed. The same formation, geologically speaking, exists in eastern Wyoming that is found in the western Dakotas and throughout western Nebraska, Kansas, and eastern Colorado. The average duty of water in Wyoming is estimated at one cubic foot per second during the irrigation season. The average expense of irrigating the land by the system of ditches now in vogue is about $10 per acre.

The unrecorded ditches are small farm trenches made by the plow as a usual thing. But very little corporation work has yet been done in the State. Combinations of farmers and ranchers have been made to construct ditches needed. Under the constitution of Wyoming the open waters of the State are declared to be public property, inalienable from the land, common in use for beneficial purposes, and subjected to the supervision of the State authorities. The management of the water supply and its distribution is intrusted to a State board of control, consisting of the State engineer and the superintendents of the water divisions. Under Territorial authority, their duties were imperfectly performed by the county clerk, district court, and Territorial engineer. The latter is now a State officer. This State board is a new feature in irrigation legislation, but its formation has met with marked approval throughout the arid region. Under laws brought over from the Territorial period, ditch owners are required to file in the office of the county clerk a statement showing the capacity of their ditches, location, and average water supply, with any other facts that may be called for to make a complete record. No penalty has been attached to this requirement, and as statistics show it has often been disobeyed. The hydrography of Wyoming is such as to form only four great divisions or drainage systems. These are now recognized in the State engineer's office. The first is a continuation of the North Platte and its tributaries. The Platte River is one of the most important water channels along the eastern slope of the Rocky Mountains. It rises on the western slope of Longs Peak, in Colorado, and drains an extensive area before entering Wyoming. Owing to its northern detour, it drains the waters of a large area within the borders of the new State, running a length from the Colorado border to that of Nebraska of 350 miles, the major portion of which is of such a character that the waters may be readily diverted to agricultural uses.

Division No. 2 embraces all of the streams east of the Big Horn Mountains, a region of fine farm region in the central, northern, and northeastern portions of the State. This division comprises, with others, the agricultural counties of Johnson and Sheridan.

Division No. 3 includes the Big Horn River and its tributaries. It drains a large proportion of both the Wind River and the Big Horn Mountains.

Division No. 4 is watered by the Green, Bear, and Snake rivers, with their tributaries lying to the west of the continental divide. In this division there is abundant opportunity for the construction, on a large or small scale, of a system of storage reservoirs and of canals and other works necessary for water supply and distribution. Very few prior appropriations have been recorded therein, and but little has been done in the direction of irrigation. The division has great opportunities and offers a large field for those interesed. Being free from legal disputes and largely unoccupied, it may easily be made the seat of a scientific yet simple system of irrigation works framed on a large scale, and therefore economic in character.

State Engineer Elwood Mead, under date of October 30, 1890, made to the governor a report on the condition of irrigation in Wyoming for the current year. The last Territorial legislature had failed to make an appropriation for the expenses of the engineer's office, and as a result its usefulness was largely curtailed. River gauging and similar work was, however, carried forward by local assistance. The most important station established was on Clear Creek, near Buffalo, Johnson County. This is the center of a large and important arable area, watered by numerous mountain streams. The lack of funds largely impeded the progress of field inquiries, and the engineer confined himself to a consideration of legal questions, water-right disputes, and the most obvious and equitable modes of settling them. As Engineer Mead presented to the Senate Committee on Irrigation a very full report of developments up to the close of 1889, there remained but little of actual work to chronicle.

The most important work has been in the western part of the State. Along the tributaries of the Green River considerable land has been reclaimed and construction begun on one large canal. In other parts of the State but little has been accomplished in the way of the building of new work, the tendency being to await further action by Congress in regard to the public land, and the enactment of the State laws controlling the public waters.

The year has been prosperous for completed irrigation works, as the water supply has been abundant in the western portion of the State. Elsewhere complaints have been few. Crops were generally excellent in yield and quality.

The report closes with suggestions as to the future work of the State board of control and of the State engineer's office.

Under date of December 31, 1891, Mr. P. L. Naismith, assistant State engineer, forwards, through the courtesy of Hon. F. E. Warren, United States Senator, the following statement:

Summary of irrigation development by districts.

I.

[State engineer's report for 1891.]

	Total number of recorded ditches.	Total lengths stated.	Total capacity as given. (In miner's inches.)	Total acreage watered as given.	Number of ditch claims, omitting statement of capacity.
		Miles.			
1*	643	1,322.4	5,911.6	482,434	48
2	327	582.8	6,649.8	379,165	53
3	282	317.4	3,644.1	395,563	72
4 †					
5	502	996.4	10,422.7	440,540	57
6	124	197.0	1,556.0	58,162	36
7	322	518.2	1,659.0	108,977	96
8	182	212.4	3,095.5	35,395	79
9	49	91.4	342.0	42,460	25
‡	7	11.9	136.8	4,180	
Total	2,438	4,249.9	33,417.5	1,946,876	466

* Seven reservoirs additional.

† District No. 4 omitted because of incomplete record.

‡ Unorganized district.

II.

	To January 1, 1891.	During year of 1891.
Total number of ditches	3, 080	*a* 210
Total length of ditches, miles	5, 464	970
Total capacity, in cubic feet per second	2, 563, 900, 000	....
Total acreage under ditch	2, 172, 781	856, 700
Estimated cost of ditches per acre	$3. 62	....
Total cost of ditches	$7, 865, 467. 22	$3, 464, 269

a Applications.

In response to your inquiry as to the irrigation development of Wyoming, I would say that the law of 1886 required that a statement of claim as to the size, length, capacity, etc., of all the ditches built prior to that date be filed with the county clerks of the different counties, and that henceforth a statement of all proposed ditches be filed before the construction of the same is commenced. The new irrigation law, approved December 22, 1890, required that these records be transferred to the office of the State engineer, and that henceforth all ditch records be kept there. These are now at hand, and from them the inclosed table as to the irrigation development up to January 1, 1891, has been prepared. The tendency in most cases has been rather to overestimate than to underestimate the acreage under ditch, but from observations made by the engineer's department and the board of control during the past season it has been estimated that fully 15 per cent of the ditches have never been recorded, so that the acreage stated in the table can be taken as fairly approximately correct.

The new law requires that henceforth a permit be secured from the State engineer before the commencement of the construction of any ditch within the State. The application for this permit must state the proposed length of the ditch, its size, estimated cost, length, and a plat must be filed, showing its proposed location, together with the land proposed to be watered.

There have been filed in this office during the past year two hundred and ten applications, from which the inclosed table, as to the development during the past year, has been prepared. In addition to what is there stated, there was one application for a permit to divert the waters of the North Platte River within the State borders, but as the greater part of this proposed ditch is to be in Nebraska it has not been included. However, I might state that the proposed length is 275 miles, and that its estimated cost is $3,000,000.

It might be well to remark, however, that while undoubtedly the great majority of these ditches have already been built, or will be built within a reasonable time, there are some which represent opportunities, rather than actual ditches. Of the two hundred and ten applications, there are five the estimated cost of which is $2,750,000, which it is to safe to say will never be built unless the lands reclaimed can be made a basis to secure the money spent on their reclamation.

ANSWERS FROM CORRESPONDENTS.

The following data is compiled from answers to circulars received by this office:

CARBON COUNTY.

Saratoga (post-office), J. H. Mullison (October 1, 1891):

Water supply: North Platte River flows 2,772 feet per second at lowest stage. Irrigation works: 25 miles, main ditches and laterals; 3 ditches—No. 1, 10 feet on bottom, 2 feet deep; No. 2, 12 feet on bottom, 2 feet deep; No. 3, 4 feet on bottom, 2 feet deep. Headgates 3; lateral gates, about 150.

Dams 3: No. 1, 150 feet long, 3 feet high; No. 2, 180 feet long, 5½ feet high; No. 3, 250 feet long, 2 feet high, reservoirs, 2.

Area under this system under ditch, 1,200 acres, under cultivation 1,000 acres. Total area irrigated and in crops in Carbon County, 39,869 acres; number of irrigators in county, 272.

Average cost per mile of ditches (this system), about $25 including laterals. Cost of reservoirs, $150 each.

Average cost per acre of works, ditches, etc, $2.50; annual maintenance and repairs per acre, about 25 cents; for preparing land for cultivation under irrigation, $10 per acre; for grazing, $2.50, per acre. Cost of water supply to user per acre, 25 cents.

Products under irrigation: Hay, grain, vegetables.
Estimated value of product per acre, about $15 (separate from grazing).
Estimated value of product per acre, for Carbon County, $6.83.

Saratoga (post-office), L. G. Davis (October, 1891): Saratoga Land and Irrigation Company:

Water supply: North Platte River.
Irrigation works: 14 miles main ditch, about 20 feet wide on bottom at head; average width 10 feet on bottom; about 15 miles of laterals; one main headgate, about 20 small ones for laterals; one dam 300 feet long, 20 feet wide; capacity of ditch at upper part, about 200 cubic feet per second.
Cost per mile of main ditch, an average of $750; cost of dam $1,000.
Average cost per acre for main ditch and laterals, about $2.
Average cost per acre for maintenance and repairs per annum, from 5 to 10 cents.
Average cost per acre for preparing land for cultivation through irrigation: $5 to clear, plow, and seed to oats or wheat sage-brush land.
Area under ditch, 8,000 acres; area under cultivation under this ditch, 3,000 acres.
Chief products under irrigation: Oats, wheat, and barley are principal cereals; alfalfa, timothy, and native grasses; potatoes and other vegetables.
Average yield of products per acre: Oats, 25 bushels; wheat, 20 bushels; barley, 25 bushels; potatoes, 400 bushels; alfalfa, 4 tons; timothy, 1½ tons; native hay, 1 ton.

Saratoga (post-office), Fred. Mathyas, C. E., (October, 1891):

Represents a company anticipating the construction of two systems of irrigation—first, to take water from Medicine Bow River, 650 cubic feet per second, to irrigate lands in townships 19 and 20, ranges 83 and 84; second, to take water from Brush, Barret, and French creeks, 400 cubic feet per second, to irrigate lands in townships 16, 17, and 18, range 83 west.
Works: Two main canals, 20 miles in length each—first, Medicine Bow Canal, 20 feet base at headgate, depth water 7 feet, slope 1 to 1; second, Brush Creek Canal, 18 feet base at headgate, depth water 4 feet, slope 1 to 1; 5 reservoirs located. Total area, 12,200 acres; largest dam to be 500 feet long, 62 feet high (rock).
Headgates and waste weirs: Medicine Bow Canal has 4 (also 14 drops, 6 feet each); Brush Canal, 5; headgates for laterals not planned yet.
Estimated cost of canals per mile: Average, $4,000; 5 reservoirs, $120,000.
Estimated cost of water to user per acre, $3.
Estimated area covered by these two systems, 120,000 acres and 90,000 acres.
Estimated area under ditch between mouth of Brush Creek and Fort Steele, along river, 6,000 acres; under cultivation, 1,200 acres.
Average cost per acre in neighborhood for preparing land for cultivation, $6 (sage brush).
Average cost per acre in neighborhood for farm or private ditches, about $2.50.
Average cost per acre in neighborhood for maintenance and repairs, 15 cents or less.
Products: Hay and pasture; yield of hay, 1 ton per acre.

Durbin (post-office), John Durbin (October, 1891):

Water supply: Muddy Creek, mountain stream; abundant supply in spring months.
Irrigation works: 2 miles of ditch, 4 feet on bottom; one headgate.
Area under ditch, 400 acres; under cultivation, 60 acres, and 100 acres of hay land.
Average cost per acre for preparing land for cultivation, $5 (sage-brush or greasewood land); cost per acre of main ditch, $1.50; cost for annual maintenance and repairs, very small.
Cost of water supply to user per acre, $1.50.
Chief products under irrigation: Hay, oats, and potatoes; yield of hay per acre, 1 ton.

CONVERSE COUNTY.

Douglas (post-office), secretary of Douglas Ditch Company and W. D. Pease, C. E. (September, 1891): Surveys for ditch made, plats completed, etc., but construction work not yet begun.

Water supply: North Platte River; supply unlimited.
Mileage and size of ditch: 40 miles; 15 feet wide at bottom, 22 feet at top; 1 headgate; no reservoirs; ditch cuts from river and reaches the surface within first mile.
Estimated cost per mile of ditch, $2,000 to $4,000; cost per acre, $7.
Average cost per acre for preparing land for cultivation, $3 to $10, including ditches.
Average cost per acre for annual maintenance and repairs, 25 cents to $1.
Area under ditch, 15,000 acres.

Chief products under irrigation: Alfalfa, wheat, oats, potatoes, and other vegetables.

Average value of products per acre, $35.

Average yield of products per acre: Hay, one-half to 1 ton; wheat, 30 to 40 bushels; oats, 70 to 80 bushels; potatoes, 200 bushels.

JOHNSON COUNTY.

Buffalo (post-office), Gustave E. A. Mohler (October, 1891).

[Data for county generally.]

Area under ditch, 250,000 acres; under cultivation, 116,544 acres.

Water supply: Big Horn River, Powder River, No Wood River, and the following creeks: Shell, Painted Rock, Medicine Lodge, Ten Sleep, Cañon, Deep, Kirby, Crooked, Crazy Woman, Clear, French, Rock, Johnson, Sayles, and Piney. All except the first-named river have their sources in the Big Horn Mountains.

Works, mileage, and size of ditches: 3,160 miles, varying from 16 feet on the bottom and 25 feet on top to 1 foot top and bottom; headgates, 420; no reservoirs.)

Cost per mile of ditches, from $30 to $1,200.

Cost per acre of water supply to user, from $1 to $5. (This has been about the cost per acre of works, ditches, etc., but ditches now taken out to reclaim land will cost more, as all land near water courses has already been taken up and reclaimed.)

Average cost per acre for annual maintenance and repairs, not over 25 cents.

Annual rental cost for water supply, from $1 to $1.65 per acre.

Chief products under irrigation: Oats, wheat, barley, potatoes, and hay.

Estimated value of products per acre: Grain, $35; potatoes, $75; hay, $25.

Trabing (post office), John R. Smith (October, 1891): Has 1,200 acres under (his own) ditch; under cultivation, 700 acres in grass, 90 acres in grain.

Water supply: Crazy Woman Creek, 6 feet of water.

Works: Ditch 6 miles, 7 feet on bottom, 9 feet on top; one reservoir; dam about 40 yards long; one main headgate; one waste gate; 80 or 100 lateral gates.

Cost per mile of works (ditch, dam, reservoir, and gates), $1,000; average cost per acre of works, ditches, etc., in vicinity, from $3 to $8.

Average cost per acre for preparing his own land for cultivation under irrigation (and cost of his land, etc.): Government land, $1.25 per acre; ditching, $5; grubbing sage brush, $2; plowing, $3.

Cost per acre for annual maintenance and repairs: About 25 cents.

Chief products under irrigation: Wheat, oats, rye, barley, alfalfa, blue-stem grass, timothy, clover; all kinds of garden products.

Average yield of products per acre: Wheat, oats, rye, and barley, from 35 to 40 bushels.

SHERIDAN COUNTY.

Sheridan (post-office), Simon J. Evans (October, 1891):

Works in progress: 8 miles of ditch, 5 feet on bottom, 600 feet tunnel in sandstone, 2-foot dams. Water supply not stated.

Cost per mile unknown; area under ditch not stated.

Average cost per acre for preparing land for cultivation under irrigation, $5 to $6.

Average cost per acre for irrigation works, ditches, etc., $10 to $20.

Average cost per acre for annual maintenance and repairs, $1 to $1.25.

Products: Wheat, oats barley, corn, alfalfa, timothy, clover, all kinds of vegetables and small fruits.

Average product per acre: Wheat 30 to 50 bushels, oats 40 to 60 bushels.

UINTA COUNTY.

Evanston (post-office), Wm. Hinton (October 1891):

Water supply: Bear River—"Bear River and Yellow Creek Canal" (system now under construction).

Works: Two and one-eighth miles main canal, 16 feet on bottom, 20 feet on top, 3 feet of water; grade, $5\frac{28}{100}$ feet per mile; laterals, about 40 miles; one main headgate in 3 sections (reservoirs contemplated).

Cost per mile for main ditch or canal, about $4,000.

Average cost per acre of irrigation works, ditches, etc., in neighborhood, about $4. (Lands near water courses have been irrigated at a cost not exceeding 50 cents per acre; expense will be greater hereafter.)

Average cost per acre for preparing land for cultivation under irrigation, $10 (including clearing and grubbing brush, plowing, leveling, and fencing).
Average cost per acre for annual maintenance and repairs, about 50 cents.
Area under ditch in Bear River Valley, 200,000 acres, one-half under cultivation.
Product: Principally hay crop, alfalfa, timothy, and native grasses.
Yield per acre, from 1 to 5 tons—2 tons a fair average.

CENSUS FIGURES.

The United States Census Office (Bulletin 107) reports for this State (Mr. F. H. Newell) as follows for the enumeration year 1889-90.

Number of counties	12
Number of irrigators	1,917
Total acreage irrigated and in crops	229,676
Average size of such farms	119
Average value of products per acre	$8.25

ON THE GREAT PLAINS.

The final reports of the field staff of the artesian and underflow investigation are a full presentation of the physical conditions of irrigation possibilities of the Great Plains region, rendering any further effort a work of superorogation. The following statements are, however, summarized from reports received in this office, and have value as a record of facts:

KANSAS.

Principal irrigation systems.

[J. W. Gregory, Garden City, Kans.]

Name of canal.	Name of owner.	Sources of water supply.	Location (counties).	Main canal.	Laterals.	Capital stock of company.	Amount now invested.	Acres irrigated.	Acres irrigable.
				Miles.	*Miles.*				
Eureka	W. Kans. Water Works and Irrigation Co.	Arkansas and underflow.	Gray, Ford, and Edwards	96	150	$1, 000, 000	$2, 000, 000	3, 000	50, 000
South Side	South Dodge Canal Co	Underflow.	Ford	15	20	250, 000	50, 000	1, 000	15, 000
Garden City	Garden City Irrigation Co	Arkansas River.	Finney	10	20	300, 000	15, 000	4, 000	10, 000
Kansas	do	Do.	Do	20	30	....	35, 000	8, 000	20, 000
Southwestern	Southwestern Irrigation Co	Arkansas and underflow.	Kearney and Finney	40	85	200, 000	60, 000	10, 000	50, 000
Western	Western Irrigation and Land Co	Do.	Do	25	40	250, 000	200, 000	5, 000	25, 000
Amazon	Syndicate Lands and Irrigation Co	Do.	Kearney, Finney, and Scott	99½	75	2, 000, 000	325, 000	2, 000	34, 000
Alamo	Alamo Irrigation and Manufacturing Co.	Arkansas River.	Hamilton	30	70	10, 000	35, 000	2, 000	15, 000
Englewood	Claremont Land and Irrigation Co	Cimarron River.	Clark	8	6	....	7, 000	600	2, 000
Emerson (1, 2, 3, and 4)	S. F. Irrigation and Improvement Co	S. F. Republican River.	Cheyenne	70	25	100, 000	150, 000	....	35, 000
Ward	Ward Irrigation Co	Solomon River.	Phillips	10	5	24, 000	5, 000	200	....
			Total	423½	526	4, 134, 000	2, 882, 000	35, 800	256, 000

Mr. Gregory also gives the following list of organized companies:

The Des Moines and Western Irrigating and Land Company, Medicine Lodge, Barber county, capital stock $25,000.

The Consolidated Irrigation and Water Power Company, Dodge City, capital $1,000,000.

The Interstate Irrigation Company, Leoti, Wichita county, capitalized at $500,000.

The Smoky Hill River Irrigation Company, Russell Springs, Logan County, capital stock $1,000.

The Irrigation Land Company, Topeka, capital stock $251,000, to do business "in Colorado and surrounding States," with headquarters at Topeka, Kans., and at Las Animas, Colorado.

The Western Kansas Waterworks and Irrigation Company, Dodge City, capitalized at $2,000,000.

The Smith-Buck Irrigating Ditch Company, St. Francis, Cheyenne county, stocked at $5,000.

The Arkansas Valley Land and Irrigation Company, with headquarters at Vera, Waubaunsee County, capitalized at $1,000,000. The place chosen as the headquarters of this company is on the 96th meridian and outside even the semi-arid region.

The Northwestern Kansas Irrigation Company, of Colby, Thomas County, capital stock, $50,000.

The Union Pacific Canal and Land Company, Sharon Springs, Wallace County, capital stock, $300,000, proposes to construct dams for irrigation and water power.

The Kendall Irrigation and Manufacturing Company, Kendall, Hamilton County, stocked at $10,000; also the Kendall Canal Company, same location and same amount of capital stock.

The Greeley County Irrigation and Water Company, Tribune, capital $5,000.

The Lane County Irrigation Company, no place specified as headquarters, capitalized at $25,000.

The Beaver Irrigation Company, Leoti, Wichita County, capital $10,000, to take water from "Beaver and Ladder Creeks."

The Western Irrigation and Land Company, Topeka, capital stock $250,000.

The Arkalon Irrigation and Water Power Company, Arkalon, Seward County, capital stock $15,000; to take water from the Cimarron—depending largely upon underflow.

CHEYENNE COUNTY.

St. Francis (post-office), South Fork Irrigation and Improvement Company:

Water supply: South Fork Republican River.

Irrigation works: 143 miles of main canal and feeder, and other ditches nearly completed; main canal 70 miles long takes water 3 miles west of Kansas line, where it is 24 feet wide, 5½ feet deep, and terminates in a reservoir 4 miles south of St. Francis with capacity of 116,000,000 cubic feet, from which distributing ditches extend to lands of the main divide; capacity of canal, etc., 600 cubic feet per second; also works to develop the underflow and (under construction) a 20-mile ditch to irrigate the bottom lands above St. Francis, and supply that city for fire and other purposes.

Cost of works: $170,000 has been expended.

Area under this system, 50,000 acres.

Cost of water supply to user, $1,000 for a perpetual water right (1 cubic foot per second); maintenance and repairs, not large.

ELLIS COUNTY.

Ellis (post-office), W. F. King (September 22, 1891); Hays City (post-office), C. W. Miller (October 7, 1891):

One well (near a creek) 20 feet deep was pumped at the rate of 1,800 gallons per hour, without diminishing the supply; 4 or 5 acres irrigated by means of these wells. Last season rainfall was sufficient for crops. Water should be stored in reservoirs.

Very little irrigation in county; none from streams by dams or reservoirs; some small gardens are irrigated by means of surface wells 18 to 20 feet deep, mostly along streams; water being pumped by aid of windmills and others.

FINNEY COUNTY.

Garden City (post-office), C. A. Brown and James Craig (October and September, 1891):

Water supply: Arkansas River; area under ditch, 150,000 acres; under cultivation, 25,000 acres.

Works: 75 to 100 miles ditches; 20 feet bottom; 30 feet top; 3 feet deep; head gates, 4; no reservoirs.

Cost per mile of ditches, $200 to $500; laterals, $1.50; average cost per acre for ditches, etc., $1.35 to $3; annual maintenance and repairs, 25 cents to $1.50.

Average cost per acre for preparing land for cultivation under irrigation, $3.

Cost of water supply to user per acre, $1.25 to $2.

Area under ditch, 150,000 acres; under cultivation, 25,000 acres.

(Mr. Craig reports 21,000 acres under ditch; under cultivation, 7,000 acres.)

Staple products under irrigation: Wheat, oats, corn, barley, alfalfa, millet, sorghum, potatoes, cabbage, onions, fruit, grapes, berries.

Average yield per acre: Wheat, 15 bushels; oats, 40 bushels; corn, 30 bushels; barley, 35 bushels.

(Mr. Brown estimates the value of product per acre at $10 [for crops outside of forage]; forage, $25.)

GRAY COUNTY.

Ingalls (post-office), E. J. Clark, county register (September 29, 1891):

Water supply: Underflow of Arkansas River.

Irrigation works: 96 miles of ditch, 25 feet bottom, 40 feet top, 5 feet deep. Supply obtained by excavating ditches from 3 to 10 feet deep along side of the river; water obtained in quicksand below river bottom; fall of river, 7 feet per mile; 80 reservoirs from 2 to 50 feet deep; area, from 10 to 160 acres; one head gate; one waste gate 2 miles below mouth of underflow ditch.

Area under ditch, about 500,000 acres; under cultivation, 50,000 acres.

Cost per mile of works, ditches, etc.: Total cost, $700,000; average per mile, $7,291.64. (Greatest cost on first 30 miles, through hills, rock, blasting, etc.—on table-land cost was from $200 to $300 per mile.)

Average cost per acre for preparing land for cultivation under irrigation: Breaking, $2; fencing, $1.50; small lateral ditches, 25 cents; total, $3.75.

Cost per acre for maintenance and repairs: Only expense a "ditch walker" for each 8 miles, at $1.50 per day.

Cost of water supply to user per acre, $2; annual rental cost, $2.

Products: Wheat, rye, oats, barley, corn, alfalfa, potatoes, cabbage, and other vegetables and breadstuffs; orchards under irrigation quantity and quality of fruits equal to those of California.

Average yield of products per acre: Wheat and rye, 40 to 50 bushels; oats, 80 to 120 bushels; corn, 65 to 100 bushels; barley, 80 to 140 bushels; potatoes, 300 to 500 bushels; alfalfa, three crops per year, 2 tons per acre. (Sweet potatoes, pumpkins, squashes, and melons do well without irrigation.) For grazing, 3 acres under irrigation are equal to 10 acres without.

Without irrigation the yield is: Wheat, 8 to 15 bushels; rye, 12 to 18 bushels; oats 20 to 30 bushels; corn, up to 20 bushels; barley, 10 to 25 bushels; Irish potatoes are a failure three out of four years; alfalfa from one-half to three-fourths ton per acre in a moderately rainy season; dry season, none.

MARION COUNTY.

Peabody (post-office), W. H. Morgan (October, 1891):

Rainfall in Marion County has been a good average for twenty years, but farmers should build small dams across small "draws" for watering stock—not necessary for irrigation. County well watered by streams, and well water is obtained at a depth of from 10 to 60 feet, ample for all purposes, including irrigation on a small scale by windmill power.

M'PHERSON COUNTY.

McPherson (post-office), A. F. Waugh (October 7, 1891):

Irrigation very little practiced; some gardens irrigated by water from wells—raised by windmills many seasons like the present when rainfall is sufficient.

MEADE COUNTY.

Meade (post-office), A. H. Heber (September 17, 1891):

Only two farms in the county irrigated through artesian wells cultivating about 100 acres.

NORTON COUNTY.

Norton (post-office), F. M. Lockard (for William H. Stiles) (September, 1891):

This county is in the semiarid region, but has no system of irrigation; irrigation very much needed; want all the help to aid in getting irrigation under way.

PAWNEE COUNTY.

Larned (post-office), George W. Watson, superintendent (September, 1891):

Have built no works; simply have the right under our charter; farming our lands in wheat and seldom need irrigation; 6,000 acres under cultivation.

KEARNEY COUNTY.

H. H. Filley, C. E. (Kansas City, Mo.), engineer Southwest Kansas Land and Irrigation Company (October 6, 1891):

Water supply, Arkansas River.
Total mileage of main and lateral ditches, $122\frac{9}{10}$ miles; depth, 4 feet 9 inches; width, 16 feet bottom, 31 feet top, gradually decreasing to about 11 by 4 feet at end of lateral; surveys made for two storage reservoirs, aggregating 1,800 acres; number of head gates, 1 set, 8 gates; 1 aqueduct or flume (timber).
Cost of works: Partially constructed by a former company and no record of cost preserved.
Area under ditch, 60,000 to 100,000 acres; under cultivation, 3,000 to 5,000 acres.
Cost of water supply to user per acre, $2.
[Works have been in operation too short a time to give much practical data.]

Lakin (post-office), C. H. Longstreth, superintendent Western Irrigation and Land Company (September 12, 1891):

Water supply: Arkansas River; also underflow supply.
Works: 75 miles main and lateral ditches; main ditch, 25 miles long, 20 feet at bottom; one set of head gates 40 feet wide at head of main ditch; no reservoirs.
Area under ditch, 20,000 acres; under cultivation, about 4,500 acres.
Cost per mile: Main ditch, $1,500; laterals, $15 to $20.
Average cost per acre of ditches, not exceeding $5.
Average cost per acre for preparing land for cultivation under irrigation, $3 to $5.
Average cost per acre for annual maintenance and repairs, 50 cents.
Cost of water supply to user per acre, $1.50; annual rental cost, $1.50.
Staple products: Alfalfa, wheat, oats, barley, vegetables, apples, plums, pears, peaches, apricots, berries, and small fruits.

KEARNEY AND FINNEY COUNTIES.

Edward Russell (Lawrence, Kans.) (September 3, 1891): Formerly interested in irrigation works in these countties.
Average cost per acre for preparing land for cultivation under irrigation along the Arkansas River in those counties, from $2.50 to $3.
Average cost for annual maintenance and repairs, from $3,000 to $5,000 (aside from salaries of officials). "This amount would be increased if the acreage taking water was materially increased; an increase of 1,000 acres would not increase cost of maintenance and repairs, but an increase of 3,000 acres would increase the cost probably $500."
Staple products under irrigation: Alfalfa, millet, oats, barley, wheat, and corn, and sorghum is also raised, potatoes (Irish and sweet), and other vegetables, also fruits.
Average ordinary yield per acre under irrigation: Oats, 50 bushels; wheat, 25 bushels; corn, 35 bushels.

RAWLINS COUNTY.

Atwood (post-office), A. M. Wilson and Albert Hemming (October, 1891):
"Mostly subirrigation in county; supply from underflow wells and surface streams; farmers dam up the numerous streams and 'draws;' about fifteen reservoirs and dams in county, with areas of about 10 acres each; cost of works about $100 each dam; area under ditch, about 3,000 acres; cost of water supply to user per acre $2.50."
Average cost per acre for preparing land for cultivation, about $5.
Average cost per acre for works, $2.50; maintenance and repairs, 50 cents.
Products: Wheat, oats, corn, rye, barley, flax, alfalfa, potatoes, and other vegetables.
Yield of product: "Three times as much as without irrigation."

WILSON COUNTY.

Fredonia (post-office), T. Holdren (October 7, 1891):
"Beginning irrigation with windmill pump and tanks; too early to give data."

SEWARD COUNTY.

Arkalon (post-office), L. A. Etzold and T. A. Scates, secretary Arkalon Irrigation and Water Power Company (September, 1891):

"No system of irrigation in county at present in operation; nine miles of ditch to be constructed in the spring."

NEBRASKA.

CHEYENNE COUNTY.

Bayard (post-office), Thomas Winter, treasurer "Bayard Irrigation Canal and Water Power Company" (October 28, 1891):

Water supply: North Platte River (unlimited).
Irrigation works: 57 miles ditches; lower ditch 12 miles long, 15 feet at top, 10 feet at bottom; upper ditch, 45 miles; 45 foot top, 40 foot bottom; 2 headgates, no reservoirs.
Average cost per mile, about $2,000.
Area under ditch, 40,000 acres.
Area under cultivation, about 2,000 acres.
Cost of water supply to user per acre, $5.00 (perpetual water-right).
Annual rental cost per acre, $1.50.

DAWES COUNTY.

Crawford (post-office), Mr. Grubble (banker), October, 1891:
Water supply: White River, 20 cubic feet per second.
Works: Ditch not yet constructed.

Marshland (post-office), L. Snow (September 23, 1891):
Marshland Irrigation Company.
Works: Survey for ditch (22 miles) completed. Ditch to be completed within the next year.

DEUEL COUNTY.

Big Spring (post-office), John H. Abbot (September, 1891):

Water supply: (1) From streams and creeks emptying into North Platte River from the north; (2) from the North and South Platte rivers; (3) from underflow of these rivers; (4) by pumping from wells dug on the banks of the rivers.
Mileage or size of ditches, etc., not given.
Area under ditch, about 20,000 acres; under cultivation, 2,000 acres.
Not more than 1 per cent of cultivated land is under irrigation.
Average cost per acre for ditches, etc.: On bottom lands, from $1 to $2 (from underflow of South Platte River); ditches taken from small streams and creeks cost more.
Cost per acre for annual maintenance and repairs "would be small after the first few years."
No reservoirs of large size constructed. Headgates very crude.
Several steam pumps are used, which irrigate from 60 to 200 acres.
Cost of steam pumps and ditches to irrigate 160 acres, about $1,200.
Products: Wheat, rye, barley, corn, oats, potatoes, and garden truck.
["Irrigation would add tenfold at least to the product of our lands per acre."]

DUNDY COUNTY.

Benkleman (post-office), L. Morse, president "Dundy County Irrigation Company" (September 28, 1891):

Water supply: Republican River (underflow and surface water sufficient for all land that can be reached at reasonable cost).
Area under ditch, 5,000 acres; under cultivation, 1,000 acres (including meadows).
Irrigation works: 11 miles of ditch completed, 12 feet on bottom, 20 feet on top; earth banks; 1 reservoir, area 25 acres; practically no dam; 1 headgate; 3 flumes; 4 waste gates.

Cost per mile of main ditch, $350; average cost per acre, irrigation works, ditches, etc., $5; annual maintenance and repairs per acre, not to exceed 50 cents.
Staple products: Hay, alfalfa, wheat, oats, corn, potatoes.

["Ditch just completed, and only lands easily watered will be cultivated for the next year; no water rented, ditch owned by consumers."]

HITCHCOCK COUNTY.

Culbertson (post-office), W. D. Wildman (September 24, 1891):

Water supply: Frenchman River and Stinking Water Creek (about 310 cubic feet for second; annual rainfall, an average of 18 inches.)
Irrigation works: Ten miles of ditch completed; will be 70 miles long when finished (earth work, with wooden flumes); will be several reservoirs; one at Culbertson covers 10 acres; average depth, 10 feet; 2 headgates.
Cost per mile of works, $5,000 (about); average cost per acre, about $5.
Cost of water supply to user per acre, $10 (estimated for perpetual water-right).
Annual rental, cost per acre, $1.
Area under ditch, 100,000 acres; under cultivation, 25,000 acres.
Staple products: Wheat, rye, oats, vegetables of all kinds grown in this latitude; yield of wheat per acre, 40 bushels ($24).

KEITH COUNTY.

Ogalalla (post-office), C. A. Walker, engineer "Ogalalla Land and Cattle Company" (September 23, 1891):

Water supply: White Tail Creek (40 cubic feet per second).
Works: Being constructed, 6.8 miles ditch; 6 feet on bottom; 11 feet on top; one headgate.
Cost per mile, $300; area under ditch when completed, 6,000 acres; under cultivation, 500 acres.
Average cost per acre of ditches constructed in vicinity, 40 cents to $1.

[Ditches in neighborhood have been constructed within the last two years; were not used the past year, rainfall sufficient; works too new for other reliable data asked for.]

LINCOLN COUNTY.

T. B. Sweet, of Topeka, Kans. (September 12, 1891), president of company taking water from North Platte River, in Lincoln County:

Works: 25 miles ditch; top, 15 to 20 feet; bottom, 10 to 12 feet; no reservoir; wing dam, 200 feet; one headgate; fall of 9 feet 8 miles from headgate, with numerous checks.
Cost per mile of ditch, $3,000 (estimated); headgate, $5,000; dam, $3,000.
Average cost per acre of works, ditches, etc., $2.50 to $5.
Average cost per acre for preparing land for cultivation under irrigation, $3.
Average cost per acre for maintenance and repairs, 15 to 25 cents.
Cost of water supply to user per acre, $10 (for permanent water-right);
Area under ditch, 25,600 acres; under cultivation (exclusive of hay), 5,000 acres; 1,200 acres without irrigation.
Products: Wheat, oats, rye, corn, barley, potatoes.
Average yield per acre: Wheat, 25 bushels; oats, 40 bushels; rye, 35 bushels; corn, 60 bushels; barley, 40 bushels; potatoes, 150 bushels; native hay, 2 tons; very little grazing.

SCOTTS BLUFF COUNTY.

Gering (post-office), Isaac Simonson (September, 1891):
Water supply: Platte River.
Works: Ditch 22 miles long, 16 feet on bottom, 20 feet on top, 2 feet deep on grade; 5 headgates.
Area under their ditch, 50,000 acres; under cultivation, 9,000 acres (nearly). Three other ditches in county, with average of 30,000 acres covered by each.
Average cost per acre for preparing land for cultivation under irrigation, from $3 to $5; for annual maintenance and repairs of ditches, etc., 30 cents (on their ditch).
Average cost per acre for works, ditches, etc.: About $9 for ditches that irrigate only valley lands; for ditches to irrigate the table or high lands, cost is more than double.

Products: Wheat, oats, barley, rye, potatoes and other vegetables, clover, and grass. "The yield is great, but market value small."

Gering (post-office), "Farmers' Canal Company" (September 23, 1891):

Water supply: North Platte River, 700 cubic feet per second.

Works: 66 miles canal and laterals, from 30 to 6 feet on bottom; slope, 1 to 1; 5 headgates.

Cost per mile of ditches, $1,200; cost per acre, $6 to $10.

Average cost per acre for preparing land for cultivation under irrigation, $2 to $2.50; for grazing, $1.

Average cost per acre for annual maintenance and repairs, 25 to 50 cents.

Cost of water supply to user per acre, $8; annual rental cost, $1.

Area under ditch, 12,000 acres; under cultivation, 6,000 acres.

Products: Wheat, oats, barley, corn, flax, potatoes, onions, and other vegetables. Estimated average value of crop per acre, $10.

Minatare (post-office), George W. Fairfield, secretary "Minatare Canal and Irrigation Company" (September 18, 1991):

Water supply: North Platte River; appropriation, 500 cubic feet per second.

Works: Twenty-one miles of canal at present (being extended), 40 feet on bottom; slope, 1 to 1; fall, 4½ feet per mile (slope of the valley); bottom of canal at head, 3 feet below river bed; one main headgate (5,000 feet of lumber used in it.)

Cost per mile of canal, etc., about $1,200; average cost per acre, about $4; cost per acre for annual maintenance and repairs, about 15 or 20 cents.

Average cost per acre for preparing land for cultivation under irrigation, $2.50 (breaking only necessary).

Area under canal at present, about 16,000 acres; under cultivation (and hay lands), about 4,000 acres.

Products: Wheat, oats, rye, barley, corn, millet, alfalfa, clover, blue grass, some timothy, potatoes, and other vegetables; also fruits and grapes.

Average yield per acre: Wheat, 30 bushels; oats, 60 bushels; rye, 25 bushels; barley, 35 bushels; corn, 60 bushels; potatoes, 60 to 100 bushels.

SHERMAN COUNTY.

Denver (post-office), C. W. Andrade (December, 1891):

Loup City (Nebraska) Canal, Water Power and Improvement Company; supply, Middle Loup River (Nebraska); 14 miles of ditch, 10 feet bottom, slope ½ to 1; 3 headgates under construction; also has a reservoir of 90 acres; dam 922 feet long (earth), 165 feet wide at bottom, 30 feet at top, 40 feet high.

Area under ditch, 416,000 acres.

Area under cultivation, just beginning under ditch.

Average cost per mile, $7. Cost of reservoir at Loup City, Nebr., $25,000 (estimated).

Average cost per acre of canals, about $8 (for first-class canals).

Average cost per acre for annual maintenance and repairs, 15 to 60 cents (on our canals about 15 cents).

Average cost per acre for preparing land for cultivation under irrigation, about $2.

Cost of water supply to user per acre, $10. Annual rental cost, $1,75.

Products: Wheat, oats, rye, barley, corn, alfalfa, and potatoes. Sugar beets yield largely.

Average yield of products per acre: Wheat, 30 bushels; oats, 50 bushels; rye and barley, 30 to 40 bushels; corn, 60 bushels; alfalfa, 4 tons.

NORTH DAKOTA.

DICKEY COUNTY.

Ellendale (post-office), M. F. Merchant, chairman Dickey County Irrigation Committee (September 29, 1891):

Water supply: From Ellendale city artesian well.

Has 40 acres under ditch; 13 acres under cultivation past season.

Irrigation works: About 1¼ miles main ditch; 2½ feet top; 1½ feet bottom. One reservoir covering ¾ of an acre, with dam about 8 rods long, 2½ feet high. One head gate.

Cost of ditch per mile, about $25; cost of dam, etc., $5.

Average cost per acre for irrigation works, ditches, etc., under artesian system, about $2 (including main ditch and reservoir).

Cost per acre for annual maintenance and repairs, not to exceed 50 cents.

Cost per acre for preparing his land for cultivation by irrigation, about $3.

Products: His land planted to cabbage, onions, and other vegetables.

Value of product per acre: Cabbage, $250; onions, $300 (cabbage at 5 cents per head; onions, 75 cents per bushel).

SOUTH DAKOTA.

BEADLE COUNTY.

Huron (post-office), L. H. Hole. (September 24, 1891):

Water supply: Artesian well.

One hundred acres irrigated.

Mode of service; The waste water from a 75-barrel flouring mill, run by water power from an artesian well, with pressure of about 175 pounds to square inch, through 1 mile of ditch; four headgates for changing course of water; no reservoirs, dams, or other works.

First cost for completing ditch $75; cost for annual maintenance and repairs, about 10 cents per acre.

Average cost per acre for preparing prairie land for cultivation under irrigation $3; no grazing lands under irrigation.

Cost of water supply to user, per acre, $1.

Staple products under irrigation: Wheat, oats, corn, potatoes, and flax.

Average yield per acre: Wheat, 40 bushels; oats, 80 bushels; corn, 75 bushels; flax, 16 bushels (potatoes not yet harvested). No grass or hay.

BROWN COUNTY.

S. W. Narregang (Aberdeen post-office, September 12, 1891), and J. H. Fletcher (Santa Clara post-office, September, 1891):

Water supply: Artesian wells, average depth, 1,000 feet.

Area under ditch in county 10,000 acres (for 1892); cultivated, 2,000 acres.

Irrigation works: Reservoir for each well with areas of from 3 to 5 acres; small ditches, 3 feet on bottom, 8 feet on top, and laterals 1 foot for distribution; also surface wells and windmills to small extent.

Service: A reservoir with area of 3 acres, irrigates about 100 acres; a 5-acre reservoir will irrigate about 160 acres.

Cost of works: Ditches, $50 to $100 per mile; reservoirs, 5 acres, $300 to $400; reservoirs 3 acres, up to $300.

Cost of water supply to user per acre, $1; annual rental, $1.50.

Average cost per acre for preparing land for cultivation by irrigation, $1.50 (plowing).

Average cost per acre of irrigation works: Cost of water, ditches, reservoirs, laterals, etc., estimated at $8 per acre.

Average cost per acre for annual maintenance and repairs, about 50 cents.

Products under irrigation: Wheat, oats, barley, corn, millet, flax, potatoes, and other root crops; sugar beets will be extensively raised. Field of wheat (hard), 30 bushels.

[One artesian well near Aberdeen irrigates 640 acres; four more now being sunk within 2 miles will irrigate 2,000 acres.]

McPHERSON COUNTY.

Leola (post-office), Ira D. Clark (September 26, 1891):

Water supply: Springs about 1½ miles from his farm, "Also the water from the melted snow on an area of 7,000 acres, coming out of a gulch at the springs."

Area under ditch, 640 acres; under cultivation, 200 acres.

Works: About 2 miles of ditch, 3 feet on bottom, 4 to 5 feet on top; average depth, 1 foot; deepest cut, 2½ feet. One reservoir, area 3 acres; 2 sluices; no dam; 2 head gates.

(There are 2 main ditches, one running east and west through the section of land, the other north and south. Works laid out by a United States surveyor; not yet completed.)

Cost per mile of ditches, about $100; cost of reservoirs, etc., about $200; cost of all works for the 640 acres, estimated by surveyor at about $400.

PENNINGTON COUNTY.

Farmingdale (post-office), Charles Hamm (September, 1891):

Water supply: Rapid Creek; heads in Black Hills; capacity, 2,500 miner's inches; fall, 12 feet per mile.

Area under ditch, 1,500 acres; under cultivation, 1,500 acres.

Irrigation works: 10 miles ditch, 4 feet on bottom, 6 feet on top, 2 feet deep; dam, 3 feet high (cottonwood log tied and filled back with gravel); 3 head gates, besides waste gates.

Cost of works, $500 per mile; average cost per acre, $3.33.
Average cost per acre for preparing land for cultivation under irrigation, $4 (breaking prairie land).
Average cost for annual maintenance and repairs, 10 cents per acre (where owners of land make their own ditches); about $200 per year for works above named.
Products: Hay, oats, and corn (mostly hay).
Yield per acre: Timothy and clover, 3 tons; native hay, 1 ton.

Rapid City (post-office), Henry Behrent (September, 1891):
Water supply: Spring Creek; limited supply; can only irrigate certain time in the spring.
Area under ditch, 400 acres; under cultivation, 55 acres (40 acres on farm of Mr. B.)
Works: Three miles ditch, 3½ feet wide, 1 foot deep (300 feet of ditch 6 feet deep). Dam, 45 feet long, 18 feet high, 50 feet wide at bottom; one reservoir formed by original channel of creek, from 35 to 50 feet wide; water backs up over one quarter of a mile; also 150-foot plank flume 40 inches wide, 16 inches deep, with truss across creek channel; one open-box head gate.
Cost of ditch per mile, about $75; cost of dam, flume, etc., $600.

[This ditch, dam and flume, etc., was completed in July, 1891. Water not yet in use.]

Rapid City (post-office), Chris. Thomson (September, 1891):
Has a ditch (to irrigate his nursery) taken out of a creek (on his own land), that was supplied with water for twelve years, this year it dried up for the first time. Ditch and flume 1 mile long; ditch 4 feet on top, 2½ feet on bottom; dam 4 feet high.
Area under ditch, 120 acres; under cultivation, 115 acres.
Cost of ditch, flume, etc, about $500.
Average cost per acre in vicinity for preparing land for cultivation under irrigation, $4 to $5.
Average cost per acre for irrigation works, ditches, etc.: Large ditches from $2 to $3; small ditches, $4 to $6.
Cost per acre for annual maintenance and repairs, 25 to 50 cents.
Staple products under irrigation: Wheat, oats and hay.
Average yield per acre: Wheat, 35 bushels; oats, 60 bushels; hay, 3 to 6 tons.

SPINK COUNTY.

Mellette (post-office), J. P. Day (September 22, 1891):
Water supply of locality: Dakota Artesian Basin; wells at depth of 900 to 1,000 feet; Pressure about 150 pounds per inch (closed), 97 pounds with 2-inch opening; water soft and apparently wholesome.
Reports a well 1,000 feet deep, 8-inch casing, 6-inch pipe; about 3 miles of ditches (to be extended to 5 or 6 miles); ditches supplied direct from wells; ditches of various sizes. Preparing to use well for power for machinery, but will not interfere with irrigation.
Cost of well, $3,000; cost of ditches per mile, $100 to $300.
Cost of water supply to user per acre, $2.
Area under ditch, about 400 acres; under cultivation, 300 acres.

Mellette (post-office), William Bird (September 22, 1891):
Water supply: 4½-inch artesian well (owns one-third interest therein).
Works: 2 miles ditch, 16 feet wide at top (in the clear); banks 2 feet high. One reservoir with area of 4½ acres; banks 4 feet high; 3 feet wide on top. One headgate.
Area under ditch and under cultivation, 160 acres.
Cost of well, $815.
Cost per mile of ditches, $50.
Cost of reservoir, etc, $250.

TEXAS.

MARTIN COUNTY.

Marienfeld (now "Stanton") post-office, Dr. L. H. Moller, Joseph Gittinger, and J. B. Koutz (September, 1891):
No surface streams in vicinity. Water supply from wells from 20 to 135 feet deep, by means of windmills and pumps. Irrigation confined mainly to small orchards, vineyards, and truck gardens. Area under cultivation not extensive at present.
Cost per acre for preparing land for cultivation under irrigation about $3.

Cost per acre for irrigation works, including well, preparing land, etc., $25 to $30.
Cost per acre for annual maintenance and repairs, mainly "wear and tear" of machinery, etc.: (Mr. Gittenger places it at $2.):
Products: Grapes, fruit, vegetables and alfalfa.
Average value of product per acre: Grapes, $50 to $300; onions (with proper cultivation), $1,000.

[Mr. Gittinger places the estimated value of product per acre at $450.]

Marienfeld (now "Stanton"), A. Rawlins, manager, "Marienfeld Fruit Growing, Gardening, and Irrigation Company" (September 18, 1891):

Water supply: Bored wells, windmill power, 20-foot windmills, 4-inch Cook cylinder, 10-inch stroke, cylinder in casing, well 96 feet (2 wells same size and depth).
One reservoir (wood), 10 by 16 (making dirt one 100 feet square).
Cost of reservoir, $30; cost of windmill, $500; cost of wells, $300.
Area under cultivation, 10 acres. No land "under ditch" so called.
Average cost per acre for preparing land for cultivation under irrigation: Grubbing, $3; breaking, $3.
Average cost per acre for entire works, wells, tanks, windmills, and breaking and preparing the land, $50.
Cost for annual maintenance and repairs, nominal.
Product: Onions, all garden truck, fruit and grapes (wishes to introduce alfalfa).

PECOS COUNTY.

Fort Stockton (post-office), O. W. Williams (September 19, 1891):

Water supply: Pecos River (near line dividing Pecos and Reeves counties); also 1 or 2 springs—sufficient to irrigate 45,000 acres.
Works: 10 miles main ditch completed; 25 feet on bottom, 30 to 35 feet on top, carrying 4 feet of water; 2 reservoirs to be built; dam 5 feet high, 60 feet wide; headgate incomplete.
Area under ditch, 8,000 acres; under cultivation, 1,050 acres.
Cost per mile of ditches, etc., $2,500.
Cost of water supply to user per acre, $5 (permanent water right).
Annual rental cost, 50 cents.

REEVES COUNTY.

Pecos (post-office), R. K. Brant (September, 1891):

Pioneer Canal water supply; Pecos River legal right to appropriate from river 1,020 cubic feet per second (taken about 12 miles north of Pecos City).
Works: 27 miles canal completed, 150 miles main laterals to be built (main canal 23 feet on bottom, 40 feet on top). No reservoirs; a 2½-foot dam to be built; one headgate, 8 sluice and lateral gates built; 3 flumes over Pecos River to be built.
Area under ditch, 100,000 acres; under cultivation, 800 acres.
Cost of water supply to user per acre, $10; annual rental cost, $1.
Cost of canal, etc., per mile: Canal uncompleted, cost unknown.
Average cost per acre for preparing land for cultivation under irrigation, from $15 to $20 to do it well.

(Works too new to give other data asked for.)

Products: Alfalfa, all cereals, cotton, all deciduous fruits and vines, vegetables.
Estimated value of product per acre: $100.

SWISHER COUNTY.

Tullia (post-office) C. C. Perrin, (September 25, 1891):

"No irrigation systems in county; no running streams. The 'Middle Tule Draw' runs during the wet season, and water is found in many so-called lakes. Irrigation confined mainly to gardens and small patches, water supply being waste water from wells raised by windmill pumps, water obtained generally at depth of from 12 to 50 feet. Some lakes hold water several months, but none the entire year. They have no outlets save in the bed or bottom. Soil porous, but seems to be clay, not sand. Most plants remain green, even while soil and air are very dry."

Cost of windmills, cheapest $30; pumps, cheapest, $6; best, $24; pipe, 4-inch, 38 cents per foot; 2-inch, 19 cents per foot.
Cost of wells (boring): Less than 100 feet, 50 cents per foot; over 100 feet, $1 to $2.

"This county is mainly undeveloped and untested."

TOM GREEN COUNTY.

San Angelo (post-office), Joseph Tweedy (September, 1891):

Water supply: Dove Creek, appropriation about 20 cubic feet per second.

Works: Twelve miles of ditches, 6 feet on bottom, from 18 inches to 8 feet in depth; no reservoirs; one dam; one headgate; no other works.

Area under ditch and under cultivation 1,400 acres.

Cost per mile of ditches, $400; cost of reservoirs and other works, $1,000.

Average cost per acre for irrigation works, ditches, etc., $4 to $5.

Average cost per acre for annual maintenance and repairs, $1 to $1.25.

Average cost per acre for preparing land for cultivation under irrigation: Grubbing (when necessary), $4; breaking $3.

Land is rented for one-third of the crop, water furnished.

Water costs the owner only annual maintenance and repairs.

Products: Wheat, oats, corn, cotton, alfalfa, millet, Johnson grass, fruit, sweet potatoes, and other vegetables.

Estimated value of product per acre, $20 to $25.

PAPERS

ACCOMPANYING

THE REPORT OF THE OFFICE OF IRRIGATION INQUIRY, DEPARTMENT OF AGRICULTURE.

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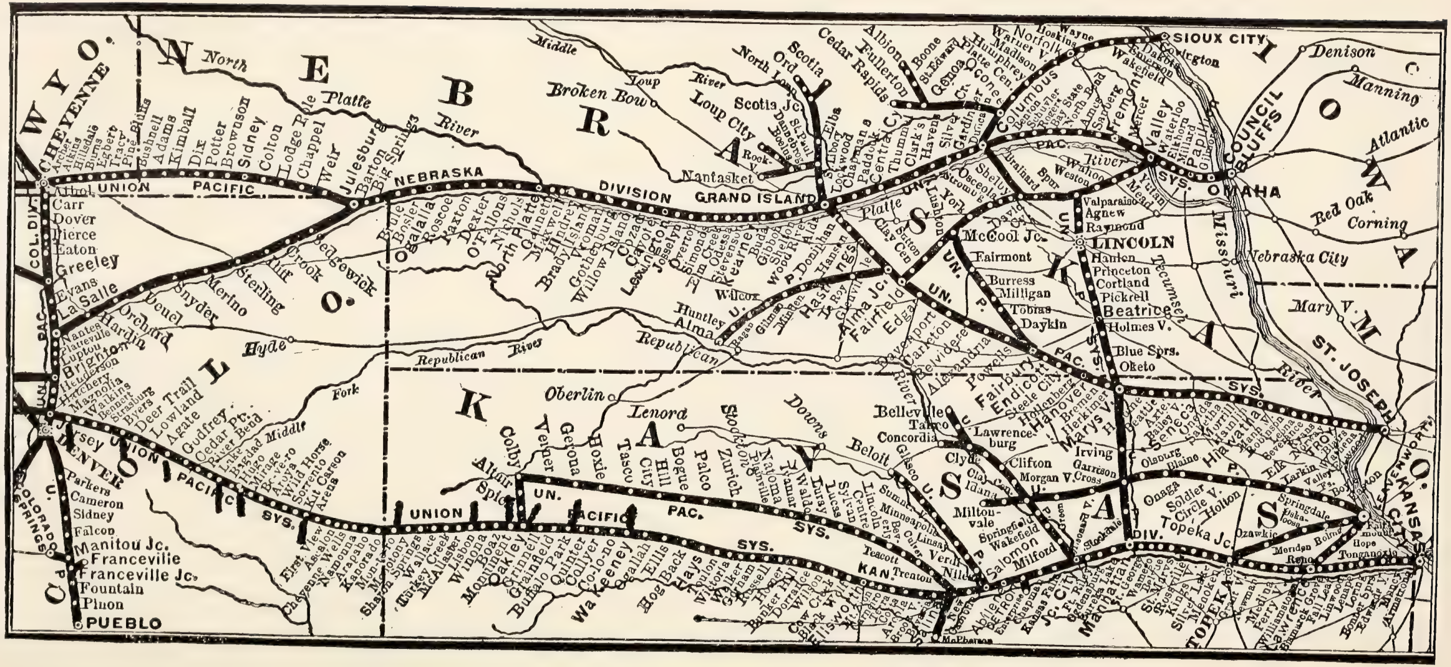

Map of Kansas Division of Union Pacific Railway.

The points marked "1" indicate the wells stations, whereat observations of underflow are being taken

PRELIMINARY REPORT ON THE POSSIBILITIES OF THE RECLAMATION OF THE ARID REGIONS OF KANSAS AND COLORADO BY UTILIZING THE UNDERLYING WATERS.

BY HOWARD MILLER, PH. D.

OCTOBER 9, 1891.

SIR: I have the honor to transmit my report on the possibilities of irrigation on the arid plateau of Kansas and Colorado.

HOWARD MILLER.

Hon. EDWIN WILLITS,
Assistant Secretary of Agriculture, Washington, D. C.

DEVELOPMENT OF THE ARID PLATEAU OF KANSAS AND COLORADO.

The last generation of schoolboys learned from their geographies that the vast and little understood trans-Missouri region was known as the Great American Desert. It was asserted, and almost universally believed, that the Plains' country included in this alleged desert would never be fit for the occupancy of man.

But as the years passed adventurous pioneers, taking the overland route to the Golden Gate, noted the streams and their fringe of forest growth and built themselves homes in the valleys.

Thus it was that the eastern portion of the so-called arid region was invaded and made amenable to the demands of civilization. From these beginnings the population spread westward, thinning and separating as it neared the Rockies.

From the river to the mountains the soil was found to be perfect, the climate all that could be desired, and the general conditions, with but one exception, most favorable.

The factor that has rendered ordinary agriculture more and more uncertain as settlement progressed westward is the lack of rain at the time of its need by the growing crops.

The elevation above the sea level from Kansas City to Denver is steadily progressive; at the former place it is 681 feet, and at Denver 5,170 feet.

To the scientist this single condition bars the continuous success of the same methods of agriculture along the line of country under consideration. There are no natural boundaries to this huge incline, but the State of Kansas is usually spoken of as being divided into three sections—eastern, middle, and western, though this classification is purely arbitrary. In the eastern portion diversified agriculture is as successfully prosecuted as in any other State. In middle or central

Kansas the seasons, whether wet or dry, play an important part in the farmer's returns, while in western Kansas it may be regarded as settled that ordinary mixed husbandry can not be relied upon with any certainty of success.

From the eastern border of Colorado to Denver the conditions of the western third of Kansas are continued.

To fully comprehend the immensity of the sections so briefly described a personal inspection is necessary. It must not be imagined that the ever-increasing altitude and the word Plains' imply a vast and perfectly level stretch of country with an imperceptible rise in grade. There are enormous reaches, aptly described by the current phrase "as level as a floor," and then there are valleys, miles between their crests, gently rising and joining hands with the blue sky.

There may be selected in this empire hundreds of square miles having any desired exposure and each so inclined that an antelope would be visible on any part of it.

On the plateau of western Kansas and eastern Colorado there are no native trees—buffalo grass covers the earth—it is green in the spring time and cures into a natural food for stock. It is a matter of surprise to the stranger that there should be thousands of cattle knowing no other food from calfhood to the shambles.

This land will produce anything that will grow in its latitude in the utmost profusion, if it only has water during the growing season. With its magic touch there may be opened up a literal garden of the gods that can feed the earth. There is but one key which will unlock this vast storehouse of the earth and make itsproducts available, and this is best symbolized by the actual fact—a ditch with flowing water.

When we speak of irrigation to the average Eastern man we put up a scarecrow, but to the Plains' man the talk is of gold.

Irrigation is as old as man's earliest efforts at agriculture. Its application is as varied as the country and locality in which it is practiced, and it may be broadly stated as the commonest form where man turns a stream into a ditch and diverts it from the main source of supply to the fields he wants to water.

If there is no available stream he may drill an artesian well and turn its waters into his fields. Between these two forms there are countless methods not germane to the subject here under consideration.

On the high plateau of Kansas and Colorado there are no available streams, nor is there hydrostatic pressure to force water above ground if artesian wells were sunk. The theory that planting forests will produce rain is inapplicable, as trees will not grow without water, and if there is water to insure their growth the trees are not directly needed. In passing, it must not be inferred that rain does not fall in the arid and sub-arid regions under consideration. It does, but the precipitation and the time of its need by growing crops are hardly ever synchronous; that is, the rain does not come when man needs it.

It is a common saying that if the country was plowed and cultivated rainfall would be produced. This is thoroughly fallacious. Climate makes vegetation and vegetation is a result, not a cause.

Plowing the soil makes it retentive of the moisture that does fall, and only thus far does the cultivation of the earth assist nature. I do not believe that this entire arid section could be cultivated, which is an utter impossibility, but assuming that it could be done, I am of the opinion that a rainfall appreciably greater would not result.

The formation of reservoirs on elevated portions of the farms has been urged, and this plan will doubtless constitute a feature of irrigation in many places.

If, then, there are no available streams on the plateau or in many other portions of the Great Plains, and if there is not a sufficient rainfall, must this magnificent country necessarily be abandoned to the herder? The writer feels that this is not a sequence of the conditions as stated, and he is of that opinion for the following reasons:

There is no fact better established than that this high altitude region is thoroughly well supplied with subterranean waters. This is shown conclusively by the fact that the railroad company to secure the water necessary for its engines has dug wells at intervals along the line. These wells are of varying depth and diameter, and are located right along the rails. They were dug for railway purposes with no immediate or remote contingency of their use for common agricultural purposes in view. Where the distance between wells allowed the company utilized a site in close proximity to a stream, or rather the bed of a stream, and in all such cases the wells are shallow. The reason is apparent. The water running down the bed of the stream percolated through and saturated the adjacent strata and the waters readily fill the well. But there are other wells on high ground, far removed from any stream or dry bed of a stream, and in all of these water is had in abundance. Of course these wells are deeper than those nearer streams. It is manifestly clear that the entire arid region is underlaid with water. This water varies in quantity and quality, but only in rare instances is it so charged with mineral matter as to be unfit for use.

Some of these wells are fitted with wind engines, and others are pumped by steam, still others have a combination of the two, steam supplementing the wheel in calm days. The water is pumped from the well to the water tank, familiar to everybody who has ever taken a railroad journey of any length.

Nothing is commoner in the vicinity of these wells than the assertion that the water supply is inexhaustible, and nothing is more incorrect, as will be shown further on.

It is well to note the fact that two theories obtain in reference to the existence of this water. One is, that it is sheet water that has percolated through the porous strata, fed from the rains and melting snows, in loco, and passing through the earth downward and laterally from the stream beds, which are invariably of sand or gravel of greater or less coarseness.

The other is that the entire plains country is underlaid with a deposition of gravel and sand, through which the waters of the streams and slopes of the Rocky Mountains slowly work their way eastward.

The writer does not know which theory is correct. It is certain, however, that water underlies the arid region. If it should be established that it exists in sufficient quantities to be made available on a large scale, the question is then one of simply raising the water to the surface and properly distributing it—problems easy of solution. If this underlying water is simply slow seepage, readily exhausted from the well, then neither ditches nor reservoirs are available, and the land inures to the stockman. If, however, this water varies in quantity, if there is a rise or fall, depending on freshet or season, and a practically inexhaustible supply by reason of its being caught on the rise and stored against the day of its use, then is the great American Desert to be renamed and known as the Great American Garden.

Can this fact be determined? At first blush it would seem an impossibility, yet the writer not only believes it possible, but is at the present engaged in the settlement of the question. To do this satisfactorily the following tests and experiments have been begun;

Along the line of the Union Pacific Railway there is a number of dug wells. The line passes through the very heart of the area under discussion, and every well taps the subterranean supply of water, the very lifeblood of this section, that must be made to flow through the arteries of an irrigation system to make this country available as a field for agricultural operations. These wells vary in size, depth, and water supply. They were constructed with a view to securing water for the engines, and when this had been attained the work was finished. A brief description of one of these wells will get before the general reader an idea of their usual make-up. At Weskan, in western Kansas, within a few miles of the eastern border of Colorado, on high ground, removed from any stream, is one. It is 132 feet deep, walled with huge stones, is 12 feet in diameter in the clear, and has 11 feet of water. Just above the surface of the water, at the bottom of the well, on a stout platform laid on timbers built into the wall, is a steam pump operated by an engine on the ground at the top. The water is pumped into the tank as needed. The well reaches the sand and gravel in which the water is found.

In this well the following apparatus is set up: A round box float of galvanized iron, resembling a small cheese box, water tight, and loaded with sand, rests on the surface of the water in the well. Attached to this float is a light copper chain, which is passed up to the ground floor of the well and over a 4-inch pulley. At the other end of the chain is a leaden counterpoise balancing the float. It will be apparent that when the water in the well rises, the float rises, and the counterpoising weight sinks, keeping the chain taut. When the water falls the float drags down the weight. It only remains to attach an index to the chain at the surface, moving up and down on a fixed scale graduated into feet and inches, and every rise and fall of the water is registered. The apparatus is simple, efficient, and wonderfully exact.

The well attendant records on a prepared blank the depth of the water at sunrise and sunset before and after pumping and the amount pumped out. In connection with the well float is a thermometer and rain gauge near the tank, and thus it will be seen that the relation between the precipitation and the water in the well is readily shown.

After the Weskan well experiment had progressed favorably it was determined that the tests should be extended, and a selection of twelve wells, covering a distance of several hundred miles, was made and each one similarly fitted with floats, rain gauges, etc., and the tabulation of results begun.

It will be perceived that in any event enormously valuable results accrue from these records. If it should be demonstrated that rain or freshet has no effect on the water supply, or that the seasons bring a tide, a slow, huge wave, lifting the water in each well from the west to the east, much will be settled thereby. If, on the other hand, the seasons show no change, and the heaviest rains produce no results in these subterranean waters, the inferences are equally definite.

The experiments have not, at this writing, proceeded far enough to show results upon which to assert an established fact. The freaks of the registration at Weskan require verification and corroboration by the records of the other wells along the line. The results, will in the end, largely settle this underflow talk, of which every man has a theory, and no man *knows*. In the end, the reports are to be published, and there will be no more reasonable doubt about the result than attaches to the findings of a gauger who measures the contents of a series of barrels in a cellar every day of the year. Of course no such result may be attained without Congress authorizing, through law, the further prosecution of such work.

It is a remarkable fact that in the vicinity of these wells the residents are apt to consider them inexhaustible. This statement has been made over and over again at Weskan. Yet when the well had been fitted with the apparatus, and the pump, throwing a three-inch stream, was started, the index almost immediately recorded a fall in the water and continued to steadily fall while the pumping lasted, and a minute thereafter the water began to fill up the well. The incident is mentioned to show that the talk, the opinions of men, honest in every respect, and the facts are not always in harmony. With this principle in view the writer, although thoroughly cognizant of the results thus far acrued, does not hazard an opinion as yet. When the results of the twelve well tests are all in, and set side by side, for a series of months, the conclusion will then be a solid foundation, and a fact, not an opinion.

The results, however, amply justify the continuance of the experiments, as affecting an enormous stretch of country where there is neither running water nor storage possible from precipitation. If at the conclusion of the experiment, it is deemed prudent to further continue the test, I recommend that the most promising well be deepened till a practically inexhaustible supply *is* reached, and this, if found, reduces the whole question of the occupancy of this arid region to a powerful pump and a properly laid out ditch.

There are many places where this is done in the miniature, with a wind pump, but it is not available to the pioneer, who is never a capitalist. No individual can undertake the development of this region in the manner and on the scale here suggested. This question should be brought to a certainty by means of such preliminary development as will render private action in the premises reasonably sure of success.

The results, if successful, would be bewildering. Where the bare, brown plains stretch away in the distance, the home of the prairie dog and the antelope, no reach of imagination is required to see a mental photograph of the tree-lined village, the garden with enormous vegetables, the town about the central water supply and the green and growing crops as far as the eye can reach. It is a beautiful picture, every color of which inheres in the water underlying the scene.

The points that follow may be regarded as established facts:

(1) Every Union Pacific Railway well between Kansas City and Denver can be pumped dry.

(2) The elevation does not have much to do with access to water, showing that the water-bearing strata are not of uniform deposition.

(3) The water is generally good and is used by the residents for many miles around the wells in the more unsettled portions.

(4) Where the water is bad inorganic matter is in solution, and this varies in quantity and quality.

(5) A fairly uniform depth may be expected for wells on the same general plateau.

(6) Failure to find water is rare.

(7) No engineering difficulties present themselves, that is, none which are insurmountable.

(8) The difference in elevation between the eastern and western well test is 2,927 feet.

(9) The average fall from west to east is about 9.54 feet per mile for the distance covered.

(10) In places penetration of the fresh-water strata results in securing salt water.

The writer wishes to thank the honorable Secretary of Agriculture, and Mr. B. A. McAllaster, of the Union Pacific Railway, for their aid and sympathy in the investigation. He further thanks the well attendants, and others rendering service at the several points of test.

The tables in this report show the altitudes and locations of the well tests. Publication of the entire results later on, when their extent, accuracy, and completion justify it, will, it is hoped, be authorized by law.

METHODS OF APPLYING WATER TO LAND, AS PRACTICED IN THE CENTRAL PORTIONS OF CALIFORNIA.

By C. E. Grunsky.
Civil Engineer, San Francisco, Cal.

Irrigation is still a new art in California, and the methods of applying water to land which have found favor in different parts of the State are the outgrowth of attempts on the part of irrigators to adapt methods in use in other localities and countries to new conditions as here found. These attempts have met with more or less success, and have resulted in the adoption of a variety of methods of irrigation, each of which is more or less perfectly adapted to the peculiarities of climate, soil, and physical features of the region where practiced. When irrigation is accomplished with water from ditches the methods of irrigation may be classified as follows:*

Irrigation by flooding.
Irrigation from furrows.
Irrigation by causing a rise of the ground water.
Irrigation from subsurface conduits.

Flooding may be accomplished by turning water out of small ditches constructed on the highest ground and making it flow in thin sheets over the surface (not specially prepared) to be irrigated. This is locally called "wild flooding." Or it may be accomplished by constructing embankments of such height that the water which they restrain will cover the land. This is irrigation by flooding in checks. (A check is a compartment or basin inclosed by check levees.)

The embankments may be adapted to the configuration of the ground, each of the main embankments being placed on a contour line. The method of irrigation is then called "flooding in contour checks." If the embankments are constructed along the sides of rectangles the method of irrigation is then called "flooding in rectangular checks." The surface of the ground in a check can be made perfectly level. Irrigation in such checks is called "irrigation in level checks."

"Furrow irrigation," like flooding, is intended to supply water only to that part of the soil into which penetrate the roots of the plants, trees, vines, etc., to be irrigated. It is sometimes practiced for grain, more frequently for plants, trees, vines, etc., which are set out in rows. "Furrow irrigation with drainage" provides for the collection of all surplus water flowing through each furrow and its subsequent utilization. "In furrow irrigation" no surplus water is permitted to enter any furrow.

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*No attempt is here made to describe methods of irrigation as practiced elsewhere, but it is hoped that California's experience may prove serviceable to other sections and irrigators. This data is brought down to August, 1891.

"Irrigation by causing a rise of the ground water" can be practiced only under certain favorable conditions. It involves the rapid sinking of water from canals and ditches into the subsoils and imperfect drainage of the latter.

"Irrigation from sub-surface conduits" or "sub-irrigation," as it is generally termed, supplies water to the surface soils only through pipes or other conduits from which water escapes and permeates the soil.

It is well to bear in mind that it is just as important to conserve the moisture already in the soil as it is to add moisture. This fact has been taught by experience to the irrigators in San Juoaquin Valley, and it has become a universal custom to cultivate the irrigated tract as soon after the application of water as possible. The surface soil is broken up and pulverized. The capillary forces of the soil are reduced to a minimum and the weeds kept down. The furrows in use to distribute water are plowed in, and if the irrigation is to be repeated the same season new furrows are drawn.

WILD FLOODING.

[See Plate No. 1.]

The practice of wild flooding can best be explained by reference to the diagrams illustrating this method of irrigation. In the plan, Fig. 1, the curved broken lines represent contours and indicate a slope of the surface of the ground in the direction from E to F. A A is a supply ditch, whose water is diverted as required, at C C, into irrigating ditches.

The irrigating ditches are sometimes permanent, sometimes temporary. Out from the irrigating ditches to the right and left, at the points D, are small embankments, with nearly horizontal crests. Material for their construction is taken from their upper sides, thereby forming a depression which serves the purpose of a watering ditch. These embankments are usually permanent, and are so flat that they do not interfere with ordinary farming operations. Irrigation is commenced by turning water from the supply ditch into the irrigation ditch at C. It is checked at D by means of a temporary dam of earth, or by means of a small gate, and flows to the right and left. As soon as water attains the height of the embankment, out from D, it commences to flow over them and to flood in a thin sheet the land intervening between the first embankment and the next one below. If too much or too little crosses the embankment at any point the defect is remedied by attendants, whose presence is constantly required during the process of irrigation. At the second point, D, the operation is repeated, and so on until the surplus water reaches an inlet into a drain ditch, which may at the same time be an irrigating ditch for other lands. The preparation of ground for this method of irrigation is very inexpensive, but the cost of applying water, owing to the constant attendance required, is great. One man can irrigate from 1 to 2 acres per day by wild flooding. This method of irrigation is sometimes called "mustang irrigation."

Fig. 2 is a section from E to F. Figs. 5, 6, and 7 illustrate an improved arrangement of a 4-foot gate for a small supply ditch.

Plate 1.

Wild Flooding.

Fig. 1. Plan.

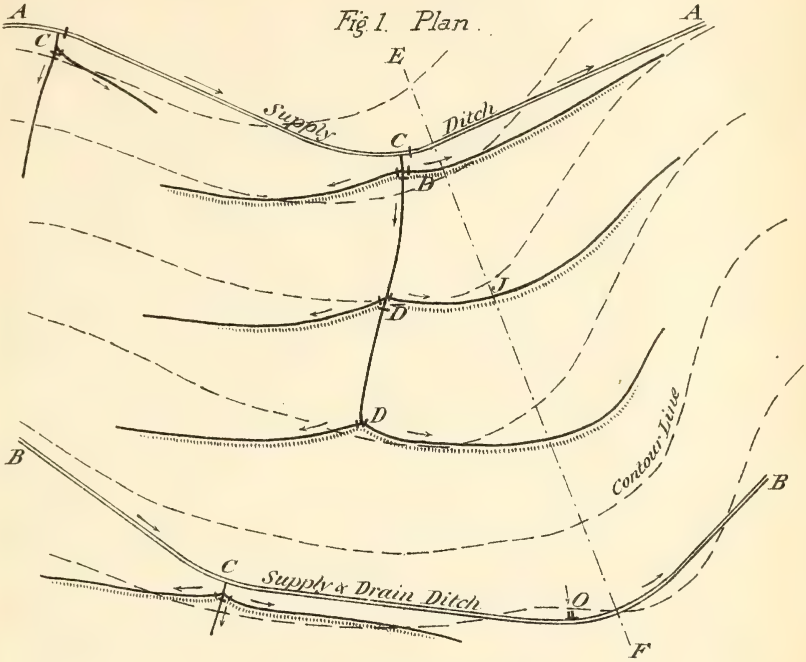


Fig. 2. Section EF.

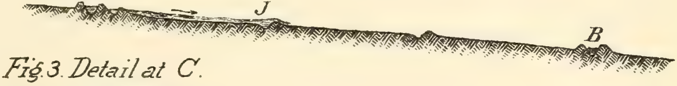


Fig. 3. Detail at C.

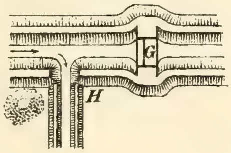


Fig. 4. Ditch at J.

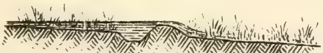
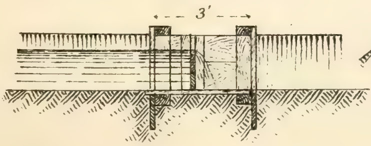


Fig. 7. Section MN.



Check Gate in Supply Ditch.

Fig. 5. Plan.

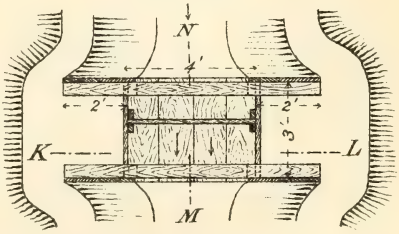


Fig. 6. Section KL.

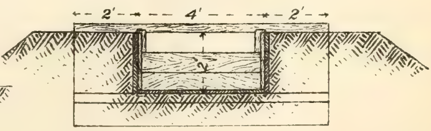


Plate 2.

Flooding in Contour Checks.

Fig. 1. Plan

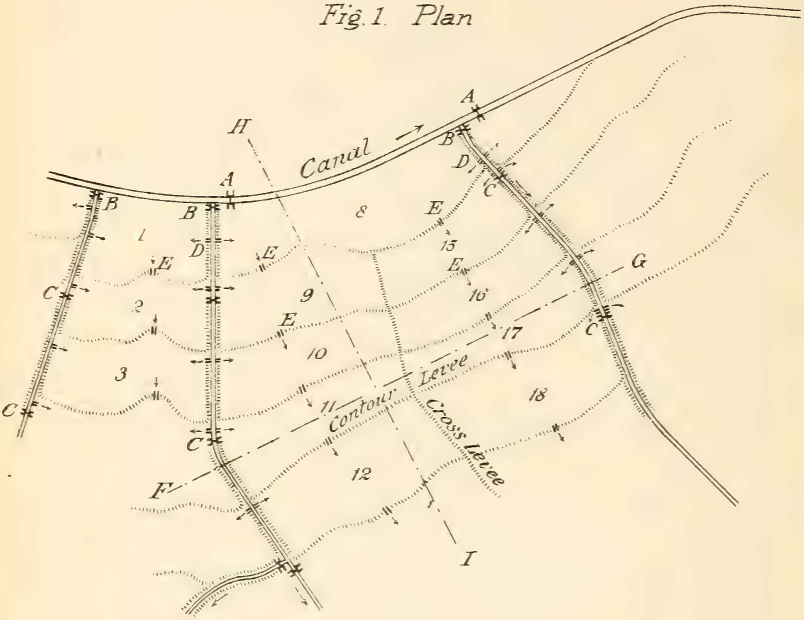


Fig. 2. Section FG (enlarged).

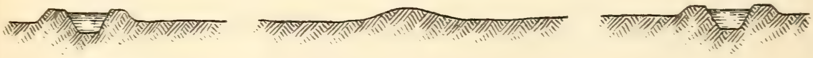
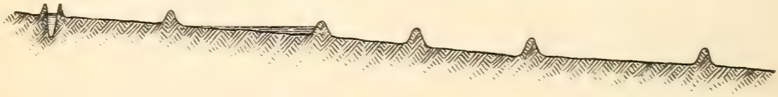


Fig. 3. Section HI (distorted).



Check-Levee Profiles

Fig. 4.

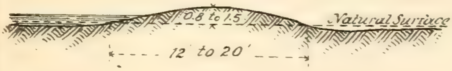


Fig. 5.

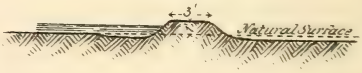
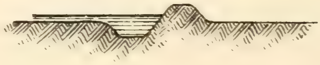


Fig. 6.



FLOODING IN CONTOUR CHECKS.

[See Plate No. 2.]

When land is to be flooded by irrigating in contour checks, water is brought to the highest points of the tract to be irrigated by means of a supply canal or ditch, from which branches may lead off about in the direction of the greatest slope of the ground surface if this be not excessive Distance between these irrigating ditches in practice is very variable, sometimes as great as one-half mile, but such distance is permissible only when very large volumes of water are available for flooding.

The farther apart that these ditches are placed the greater should be their capacity. The land between these irrigating ditches is divided into compartments by levees constructed from ditch to ditch on contour lines. These should not be made more than 12 to 18 inches high. The total fall of the ground from one to the next lower may be 6 inches to 1 foot. Where the ground is sufficiently flat to permit of less fall between the levees it is still better to adopt a fall of less than 6 inches. Where the ground is so steep that levees more than 1 foot apart in vertical elevation would be required in order to obtain the necessary space between them for the levee construction, some other system of irrigation should be adopted.

When the compartments between ditches and successive contour levees are too large they are frequently subdivided by a cross levee midway between the two ditches. This method of irrigation is illustrated by plans and diagrams on Plate No. 2.

At the points A A of the main canal are check weirs (drops or gates). At B B B are the head gates of the irrigating ditches. At C C C are check weirs in the irrigating ditches. At D D D are gates in the sides of the irrrigating ditches which serve to admit water into the compartments or checks to be flooded. At E E E are gates in the levees between checks through which surplus water of any check may be allowed to flow into the one next below it.

To irrigate the check No. 1 water is admitted into the irrigating ditches upon each side of it, and from these through D D into the check. As great a volume of water as possible is forced into this check until the countour levee backs it upon the main canal levee. As soon as this occurs the irrigation of the land in this check is complete, and the gate at E between 1 and 2 is opened at the same time the gate from both irrigating ditches into check No. 2 are opened, and the operation is repeated for each check in turn until the last check between the first two irrigating ditches has been filled. The surplus water from the last check may be disposed of into a drain or into lower irrigation canals according to local circumstances.

When all the land between the upper two irrigating ditches has been flooded water is turned into check No. 8. Should full heads of water be available for both of the ditches to the right and left of check No. 8, then the flooding of 9 and 15, 10 and 16, etc., may proceed simultaneously, otherwise irrigation should proceed in the order in which the checks are numbered in the diagram. On sandy soil or sandy loam the time required to fill a check should not exceed three hours, otherwise there will be great waste of water. If a check can not be filled in this time its size has not been properly adapted to the available head of water. Either the check is too large or there is not enough water turned in.

On heavy soil, which does not take up water so rapidly as sandy soil, time to fill a check should not exceed twenty-four hours. In practice some checks are made very large up to 60 acres in area and the amount of water turned in to flood them has been as great as 250 cubic feet per second. Such areas in one check are not advisable and should be regarded merely as temporary features of a very extensive irrigation system.

Checks with areas of 8 to 10 acres are large, and preferred sizes are 2 to 5 acres.

The embankments in use for irrigation by this method may be temporary or may be permanent. If temporary they are plowed down after irrigation so as to avoid obstructing farming operations. If permanent they may either have the profile shown in Fig. 4 or that in Fig. 5. Sometimes they are made even steeper, with still narrower crest than that indicated in Fig. 5.

The flat profile indicated in Fig. 4 is rapidly finding favor. It is the only one which can be recommended. The flat levee does not interfere with any farming operations; it is plowed and cultivated just the same as any part of the field and generally produces the best crop. It is constructed by plowing the ground to the right and left of the levee center in a strip 80 to 100 feet wide. The ground loosened by the plow is scraped toward the center and will be found sufficient for such levees as are ordinarily required. Alfalfa and grain are the crops ordinarily irrigated by flooding in contour checks.

The cost of preparing land for this method of irrigation in permanent checks ranges from $2.50 to $5 per acre, and the cost of the necessary distributing canals, ditches, and structures from $3 to $5 per acre, and the cost of the necessary distributing canals, ditches, and structures from $3 to $5 per acre. These figures, of course, may be greatly exceeded if the ground's surface has too great a slope or is very much broken by hog-wallows, or swales and ridges. Irrigation by this method is much less expensive than by wild flooding. The only labor required of attendants is the opening and closing of gates and the guarding of the check levees. When ground is well prepared for this method of irrigation, and the supply of water is abundant, the cost of each application of water will range from 3 to 30 cents per acre. The best examples of irrigation by this method are found on Kern Island, on the Calloway Canal; on Buena Vista farm, watered by the Kern Valley Water Company's canals in Kern County; near Borden and Madera, Fesno County; on the Columbia and Chowchilla ranches irrigated by the Chowchilla canal; on the west side of the San Joaquin Valley, and at various points in the Sacramento Valley.

FLOODING IN RECTANGULAR CHECKS NOT LEVELED.

[See Plate No. 3.]

When the surface of the ground is sufficiently smooth it is frequently possible to substitute a system of rectangular checks for the irregular shaped checks of the contour levee system. This may be done either by placing the main check levees as nearly parallel to the contour lines as possible, or by adapting the exterior lines of the checks to any desired course regardless of the direction of the greatest slope of the ground's surface. In this system of irrigation the main levees, as well as the cross levees, must have a varying height. In this respect it differs materially from the contour check system where the dimensions of the main check levees are uniform.

The dimensions of the levees are most variable when the levee lines

Plate 3.

Flooding in Rectangular Checks.

(not level)

Fig. 1. Plan

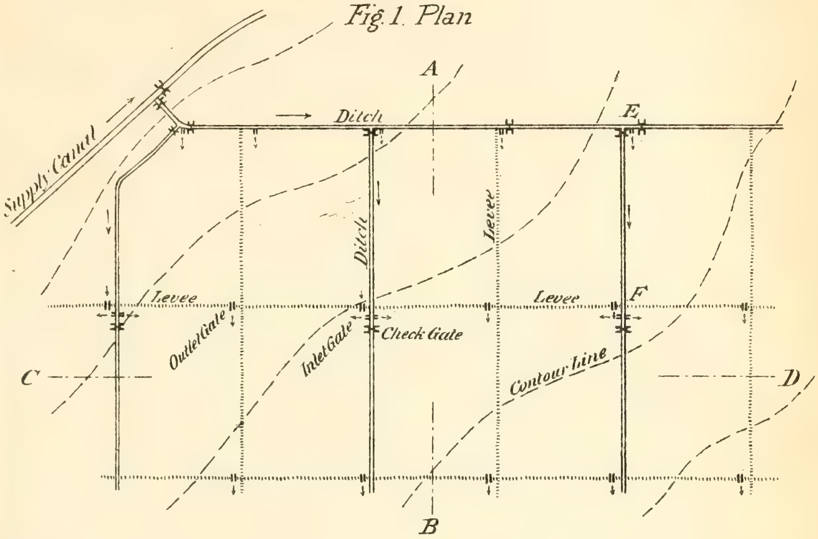


Fig. 2. Section AB (distorted)

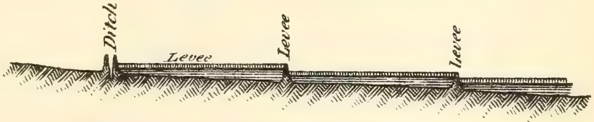


Fig. 3. Section CD (distorted)

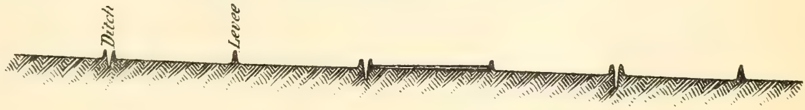


Fig. 4. Detail at E.

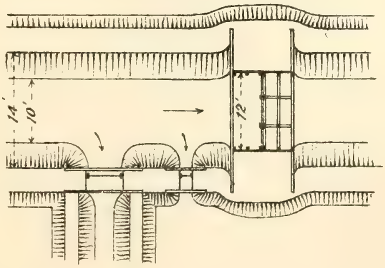


Fig. 5. Detail at F.

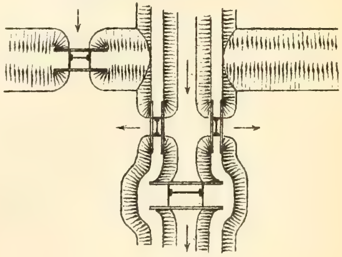


Plate 4.

Example of
Flooding in Contour and Rectangular Checks
without levelling.

(Kohler, West and Minturn.)

Fig. 1. Plan. Sec. 13, T. 9 S. R. 15 E.

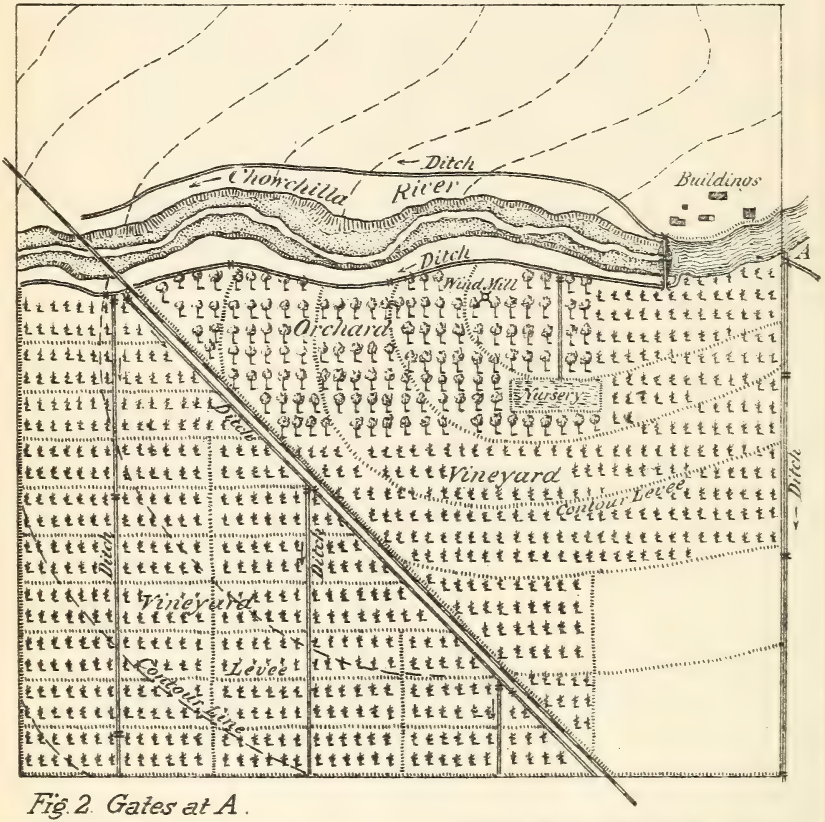


Fig. 2. Gates at A.

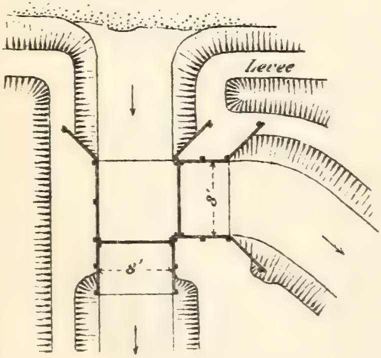
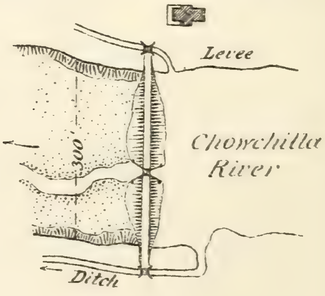


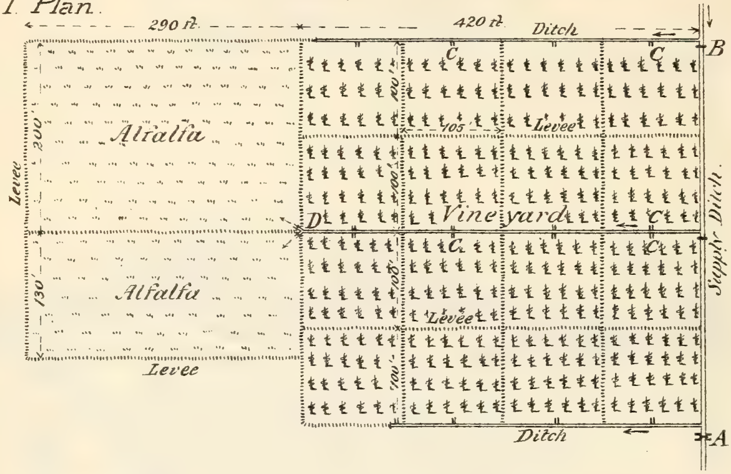
Fig. 3. Dam in Chowchilla River.



Flooding in small level Checks.

Central Colony near Fresno.

Fig. 1. Plan.



Movable Check-Gate at B.

Fig. 2. Elevation.

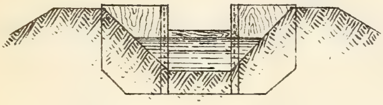
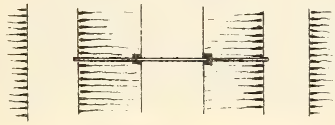


Fig. 3. Plan.



Inlet at C.

Fig. 4. Vertical Section.

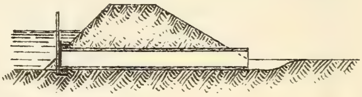


Fig. 5. Horizontal Section.

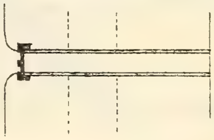
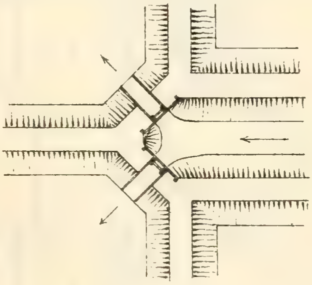


Fig. 6. Ditch and Gates at D.



Inlet-Gate at D.

Fig. 7. Section.

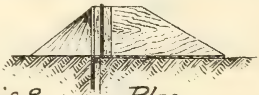


Fig. 8. Plan.

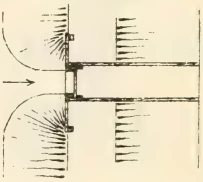


Plate 7.

Irrigation by filling Subsoils with water.

Mussel Slough Country.

Fig. 1. Plan.

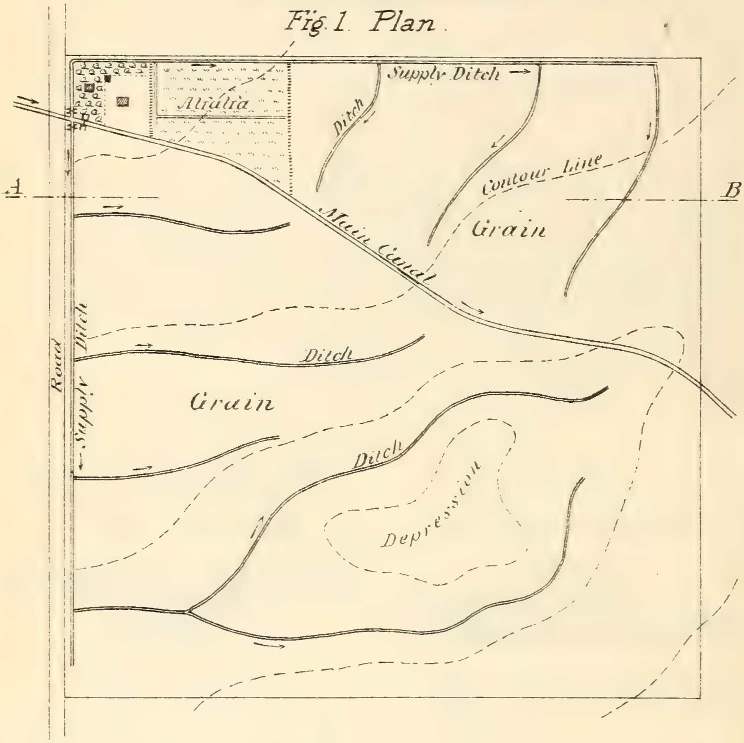
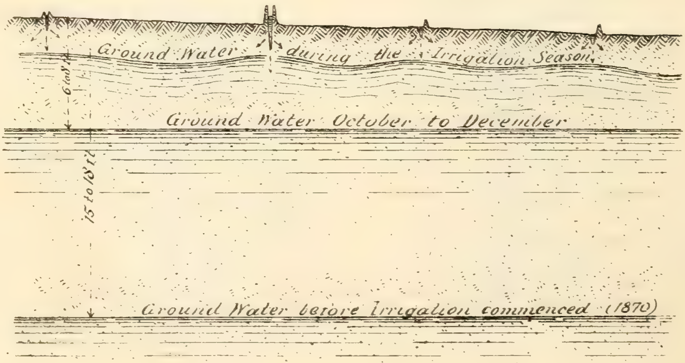


Fig. 2. Section AB.


Ground Water during the Irrigation Season.
6 to 8 ft
Ground Water October to December
15 to 18 ft
Ground Water before Irrigation commenced (1870)

are adopted arbitrarily without regard to direction of contour lines. This system of irrigation is illustrated by diagrams on plate No. 3. Ground is supposed to slope gently from the upper left-hand corner of Fig. 1 to the lower right-hand corner. The highest point of ground in each compartment or check is therefore in the upper left-hand corner. All levees as well as ditch banks must be higher above the surface of the ground at the lower right-hand corner of each check than at any other point. The size of the compartment must necessarily be smaller than would be required for contour levees unless the ground's surface be very flat. But the method of applying water after the ground has been once prepared is the same as for flooding in contour checks. The system of flooding in rectangular checks has the great advantage of permitting levees and ditch lines to be adapted to the direction of rows of trees, vines, etc., and it ought to be adopted whenever the configuration of the ground will permit.

Attention is drawn in this connection to the Kohler, West & Minturn tract, at Minturn, at Chowchilla River, Fresno and Kern counties. (See Plate No. 3.) At the time this tract was visited, in 1884, most of it had been set out to trees and vines. Irrigation was accomplished by water diverted from Chowchilla River. Part of the tract is prepared for irrigation by the contour check method, the rest by the rectangular check method.

The rectangular checks are arranged as indicated in the plan (Fig. 1). They are about 660 feet long east and west by 330 feet north and south. The method of admitting water and drawing it off from each check into the next lower one as soon as the flooding of the check has been accomplished, is the usual one already described. Water is supplied by distributing ditches, arranged about as indicated in Fig. 1.

In Fig. 3 the general arrangement of the works for the diversion of water is indicated, and Fig. 2 will explain the arrangement of the head gates in the various distributing canals. The soil of the Kohler, West & Minturn tract is a light sandy loam. Under it lies a hardpan which is quite near the surface at the eastern line of the tract, but its dip westward is greater than that of the surface of the ground. The ground water is about 14 feet below the surface.

When irrigation is in progress with a full head of water (about 16 cubic feet per second) 6 men are required to manipulate gates and guard check levees. Attendants work in two shifts of three, each for twelve hours. Where the levees are constructed on contours the area of the several checks is variable, the largest covering about 20 acres of ground. The contour levees are in 6-inch contour lines. All these are made sufficiently high to retain water to the depth of 1 foot.

Irrigation, while contour checks are being flooded, progresses at the rate of about 40 acres per day of twenty-four hours, and at the rate of 20 acres per day while the land covered by rectangular checks is being irrigated. The greater time required in the latter case is due to the two causes, that the soil in these checks is deeper than at points east of the railroad, and that water used for its irrigation is generally subdivided, being made to irrigate a number of checks at the same time, whereby in porous soil unnecessary loss of water is always entailed.

FLOODING IN LEVEL CHECKS.

[See Pl. No. 5.]

In some localities where the surface of the ground is neither sufficiently smooth nor sufficiently level to permit an application of water by either of the methods already described without too great an expense, another method of flooding has found favor. Such has been the case near Fresno. It has there become customary to prepare land for flooding by constructing rectangular checks and making the area inclosed by each rectangle of levees as nearly level as the nature of the soil would permit.

Size and relative length of the sides of the rectangular checks are always to be governed by the peculiar character of the ground's surface. It is evident that if the checks be made very long in the direction of the slope of the ground, it may become necessary to move a very large amount of material from the highest end of a check to its lower end. Very frequently the entire work of leveling consists in the cutting down of knolls and the depositing of the material thus obtained in the low places of the check and along the line of the embankment which is to surround it. It sometimes happens, as on the sandy plains in the Fresno district, that when water is applied to the land for the first time the soil is compacted, the surface settles. This settling may be quite regular, but ordinarily it is irregular, and not infrequently a caving in of the surface soil occurs in spots, leaving cavities sometimes 20 or more feet in diameter and 4 to 10 feet deep to be refilled after the first thorough wetting. Where such caving in has occurred it is quite evident that the complete leveling of the ground's surface can often be accomplished by a judicious selection of the points from which to take material for the purpose, with as little expense as a mere haphazard filling of the depressions would entail. Where the surface of the ground is of the peculiar knolly character generally termed "hog wallow" the same is true.

An example of this method of irrigation has been taken from a tract in Central California Colony (Fresno County), and is illustrated on Pl. No. 5. The plan (Fig. 1) represents the ditches and levees required to accomplish the irrigation of sixteen small checks of vines and two larger checks of alfalfa. Water is supplied by the ditch B A. It is distributed to the several checks by the ditch C D and parallel ditches. Low levees very flat, just high enough to hold with reasonable safety about 4 inches of water, surround each check. Between each two small ditches, C D, are two rows of checks. Each of the vineyard checks has an area of about one-fourth of an acre. The alfalfa checks are larger, the area of one being about 1¼ acres, that of the other three-fourths of an acre.

The irrigation of any row of vineyard checks is accomplished by checking the flow of the water in the main ditch below an irrigating ditch, as at B, and admitting the water in turn into the several checks which are to be supplied from the irrigating ditch. Irrigation, except in the case of very impervious soils, will ordinarily be complete as soon as water has been made to cover all the ground of any check to a depth of 1 or 2 inches. The more pervious the soil the more important will it be to supply a respectively large flow of water to each check. As soon as enough water has been supplied to any check the inlet gate, opening from the distributing ditch into another check, is opened and the gate leading into the former check is closed.

Wherever on sandy loam more than three hours' time is required to thus supply enough water to any check, then there is something wrong in the method of applying water. Either the size of each check ought to be reduced or the supply of water increased.

In 1882 an irrigator was observed who was engaged in irrigating four small checks of alfalfa. His water supply was small, only about 2.26 cubic feet per second. Instead of turning all the water in turn into the several checks he apportioned it to the four and the time to fill them was ten hours, whereas not more than an hour apiece would have been required had they been filled one after the other.

Returning to the example of irrigation illustrated on Pl. No. 5, it is evident that the flow of water in the ditches can be checked either by means of small gates or by means of temporary dams of earth thrown in with a shovel during the process of each irrigation. A movable check gate of very simple construction is shown in Figs. 2 and 3. It consists in the main of a notched board with narrow strips nailed to it on either side of the notch, and a set of loose pieces of boards whose ends can be slipped down the grooves formed by the strips for the purpose of closing the notch. A check gate of this character can be set across a ditch at any point where it is required in a very minutes. It can be made more secure than it would otherwise be by nailing to its lower margin and to its sides a strip of canvas to be imbedded in the material used in refilling the excavation made to receive the gate. A permanent gate as at A can be arranged as already explained by Figs. 5 and 6, Pl. No. 1.

The inlet gates at C from the small ditches to the several checks are arranged in the form of a small culvert, as shown in Figs. 4 and 5, Pl. No. 5, or they have the form represented in Figs. 7 and 8. The arrangement of levees, ditches, and gates at the point D of Fig. 1 is made clear by Figs. 6 and 7.

No drainage is combined with this method of irrigation. All the water admitted into a check is absorbed by the soil. It is to be noted in connection with the experience of the early irrigators near Fresno, that the quantity of water absorbed by or rather percolating through the soil was at times enormous. Instances have been recorded where enough water has been run on to a 20-acre tract at one wetting to cover the tract to an average depth of 5 feet, and examples can be cited where the quantity of water supplied in one season would have been sufficient to fill a reservoir of the same area as the tract irrigated 20 feet deep.

The preparation of land for irrigation by flooding in level checks is much more expensive than the preparation of land for irrigation by any of the other methods already described.

It costs about $15 to $50 per acre to put the surface in proper shape and to construct the necessary ditches and gates. But the application of water when once preparation for it has been properly made is far less expensive than by other methods, and this method of irrigation enables a very econominal use of water, because the wastage by unnecessary percolation into subsoils is reduced in the same proportion that the time required to fill individual checks is reduced.

IRRIGATION BY FILLING SUBSOILS WITH WATER.

[See Plate No. 7.]

It is not infrequently claimed that large tracts of land are irrigated by lateral percolation of water from canals or ditches. As a matter of fact lateral percolation does not extend more than a very short distance from a water course, unless the same supplies water to a very pervious soil resting on a subsoil of clay or other impervious material. The phenomenon of the wetting of the soil at some point remote from the water course which supplies the water is ordinarily due to a very different cause. Where the surface of ground water is very nearly level the effect of an additional supply of water to subsoils by downward movement of water from canals and ditches will be to cause it to rise to a higher plane. It will rise most rapidly at those points where most water sinks into the ground, but its rise may extend over a very large area of country. The hydrostatic pressure exerted by the sinking water extends in all directions, and may cause a displacement and a rise of water even at very remote points. If water sinks into pervious subsoils at many points throughout a relatively flat region it may cause the subsurface water to rise sufficiently to bring moisture from below within reach of the capillary and hygroscopic forces of surface soils.

This occurs in the Mussel Slough country and it has become the common method of irrigation in that region. The same phenomenon is observed near Fresno and at other points north of Kings River.

The method of irrigating by filling subsoils with water, as practiced in the Mussel Slough country, is illustrated on Pl. No. 7. Fig. 1 represents the plat of a tract of 160 acres. In the northeast corner is a small orchard and an alfalfa field of a few acres. The alfalfa is inclosed by a levee, so that at least once a year it may be flooded in order to exterminate gophers. A main canal passes through the tract, and from this distributing ditches are diverted and carried down along the west and north lines of the tract. About 600 feet apart small irrigating ditches lead out from the distributing ditches. These have a very slight grade in order that water may be kept at a sluggish flow in them during the irrigating season.

As soon as water becomes available for irrigation it is turned into all the ditches (which may be permanent or temporary), and the depth to ground water of October to December, as shown in Fig. 2, is gradually decreased until water is everywhere found at a depth of only a few feet below the surface. As soon as irrigation is complete water is no longer admitted into the irrigating ditches, and the depth to water begins to increase slowly. By careful inquiry it has been ascertained that before irrigation commenced, that is, before 1870, the depth to ground water ranged everywhere in this region from 15 to 18 feet. Except on the extreme edges of the region it no longer falls lower than 8 feet below the surface in the fall of the year. During the spring and early part of the summer it is held by reason of the presence of water in the irrigation ditches within 2 to 4 feet of the surface.

It will be seen that, where this method of irrigation is practiced, lands lying between irrigated tracts may derive a full benefit from irrigation without being taxed to contribute to the establishment or maintenance of the irrigation system. The mere fact that the water has been permanently raised from 18 feet below the surface to 8 feet below the surface may in many instances be a great benefit.

The system of applying water to the soil from underneath has the advantage of being very inexpensive. It is, however, open to serious objection when soils or subsoils contain much alkali. In such cases alkaline salts are carried upward by the upward moving water and their accumulation at the surface is the natural result. Many of the irrigators in the Mussel Slough region testify to such rise of the alkali, and to the fact that salt grass is crowding the alfalfa, and has not infrequently usurped parts of grain fields.

IRRIGATION FROM FURROWS.

Not the least important method of applying water to land is that which is ordinarily called furrow irrigation, and which is almost universally adopted for the irrigation of orchards, vineyards, cotton, hops, vegetables, or other plants that may to advantage be set out in rows.

Plate 6.

Furrow Irrigation of Grain.

Fig. 1. Furrows in the direction of greatest slope.

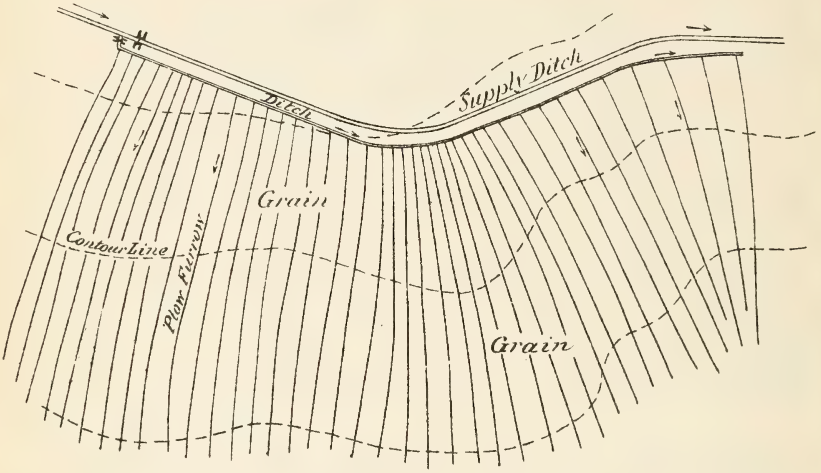
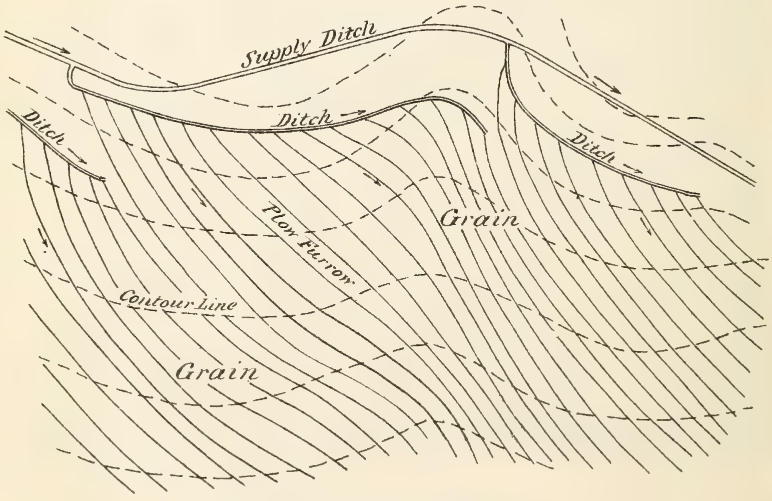


Fig. 2. Furrows at less than greatest slope.



By this method of irrigation it is aimed to moisten only those layers of soil into which the roots of trees and plants penetrate. Surface drainage is sometimes combined with this method of irrigation. More frequently, however, no attention is paid to drainage, the aim being to introduce into each furrow barely enough water to accomplish the desired end.

This method of irrigation can be best described under the following heads:

Furrow irrigation of grain—
  (*a*) With furrows in the direction of greatest slope.
  (*b*) With furrows across the direction of greatest slope.
Furrow irrigation of orchards, vineyards, etc.—
  (*a*) With drainage.
  (*b*) Without drainage.
Furrow irrigation in leveled checks.
Furrow irrigation of vegetables.
Furrow irrigation of hillside orchards, etc.

All of these special cases have been illustrated with diagrams, to which reference will be made in describing each.

FURROW IRRIGATION OF GRAIN WITH FURROWS IN THE DIRECTION OF GREATEST SLOPE.

[See Plate No. 6, Fig. 1.]

Even when water for the irrigation of grain land is available, the farmer is not inclined to burden himself with the additional expense of applying water to land so long as he may hope to have sufficient rainfall to mature his crops. In the most extensively irrigated region of the San Joaquin Valley the average annual rainfall is about 10 inches. This is sufficient to produce good crops if the rain falls at the right time. It does not always do this, and moreover the total rainfall is just as frequently below the average as above it. Consequently it often happens that water must be artificially applied in the spring of the year to refresh the parching fields of grain. If the same be prepared for flooding this method of irrigation will be resorted to. Should it be situated in a region like the Mussel Slough country, ditches will be kept full of water, and perhaps a few new ones will be constructed to hasten the rise of ground water. But if the same be not thus favored, then the question arises how to apply water to its surface most rapidly. The method which in some localities, as for instance near Kingsburg, has found favor, is that of irrigating in parallel furrows. The same method has there also been successfully practiced for the wetting of ground before it was plowed and the seed sown.

If the slope of the ground's surface be not too great, the furrows, which are generally deep single furrows, are run in the direction of the slope. They are placed 8 to 12 feet apart, according to the porosity of the soil. Water is admitted into them from small ditches, generally crossing them at intervals of 100 to 200 yards. The irrigation commences at the highest part of the field. Water is admitted into a number of furrows at one time, and by attendants this flow is checked or aided so as to accomplish a general soaking of the ground's surface. It is thus aimed to wet all parts of the field. This system of irrigation involves much labor and careful watching. It is relatively expensive.

FURROW IRRIGATION OF GRAIN WITH FURROWS ACROSS THE DIRECTION OF GREATEST SLOPE.

[See Plate No. 6, Fig. 2.]

This method of irrigation is analogous to that just described, except that, owing to too great slope of the surface of the ground, the plow furrows are run on predetermined grade lines. The greater the slope of the surface the greater must be the deviation of the furrows from the direction of the greatest slope. Ordinarily no attention is paid to properly draining the field irrigated in this way, it being the aim of the irrigator to supply just enough water to accomplish the wetting of the surface soil.

The furrows used for the distribution of water to accomplish the irrigation of grain land are, as soon as irrigation has been accomplished, plowed in, so that they may not interfere with subsequent farming operations.

FURROW IRRIGATION OF ORCHARDS, VINEYARDS, ETC., WITH DRAINAGE.

[See Figs. 1 and 2, Plate No. 8, and Fig. 2, Plate No. 9.]

Whenever any plants set out in rows are to be irrigated the natural method of applying water to the soil is that of conducting it in furrows between the rows. In this method of irrigation, when rows are far apart, it may sometimes be advisable to draw a furrow for water upon each side of every row of trees or vines. Ordinarily, however, one furrow between each two rows of trees or vines is preferred.

Furrows are generally made by plowing between rows away from the center, thus raising the ground near the rows, lowering it midway between them. The work of plowing is finished by making the last furrow a double furrow. Sometimes ditch machines, prepared especially for the purpose, as, for instance, a long log with a wedge-shaped head, are drawn through the plow furrows to finally prepare them for water.

This method of irrigation can best be explained by reference to Plate No. 8, Fig. 1. The ditches supplying water are there represented by double lines or by single heavy lines. From these water is admitted into the furrows between the rows of vines, trees, hops, or cotton, as the case may be. Care is taken to admit it at the same time to a sufficient number of furrows to reduce its flow in each, so that no washing of the soil will result. At the lower end of each furrow the water collects in a small drain ditch, which carries it off for further use. It is allowed to flow through each furrow long enough to permit a sufficient percolation into the loose soil along its course. The application of water should always commence at the highest point of the field to be irrigated. Furrows are not generally more than 300 feet long, unless the ground's surface be unusually smooth and the soil quite impervious.

FURROW IRRIGATION OF ORCHARDS, VINEYARDS, ETC., WITHOUT DRAINAGE.

[See Fig. No. 3, Plate No. 8.]

It frequently happens that the soil to be irrigated absorbs moisture so fast that there is little or no danger of supplying water to any particular spot in the field to be irrigated in so great quantity as to do injury to the plants there growing. It has therefore become a common practice to irrigate with furrows from the highest points of a field

Plate 8.

Furrow Irrigation of Vineyards and Orchards.

Fig. 1 With Drainage.

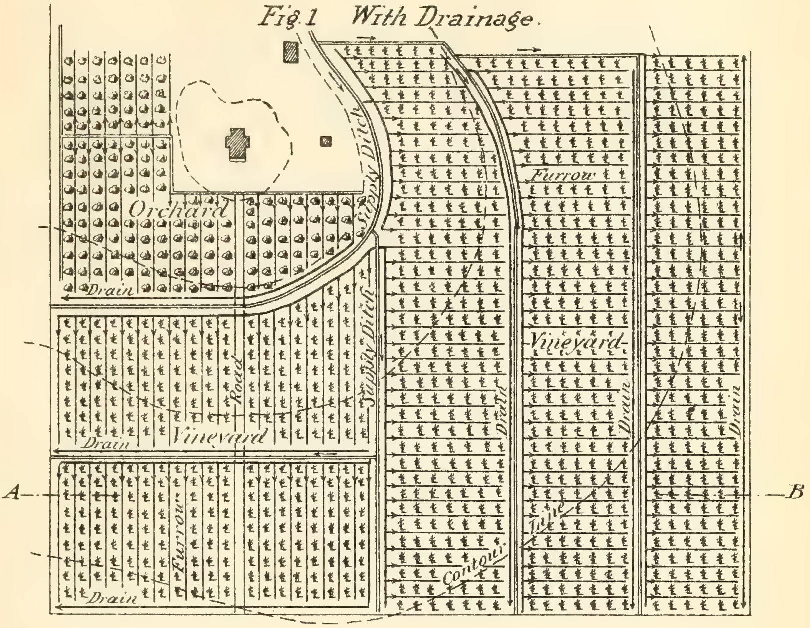


Fig. 2. Section AB.

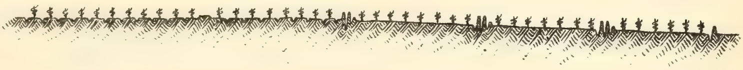


Fig. 3. Without Drainage.

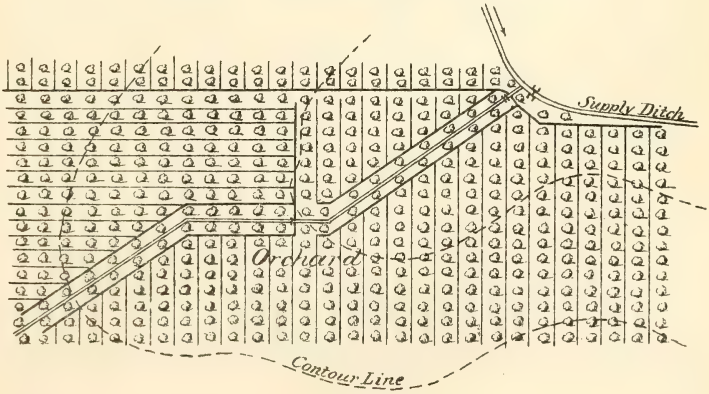
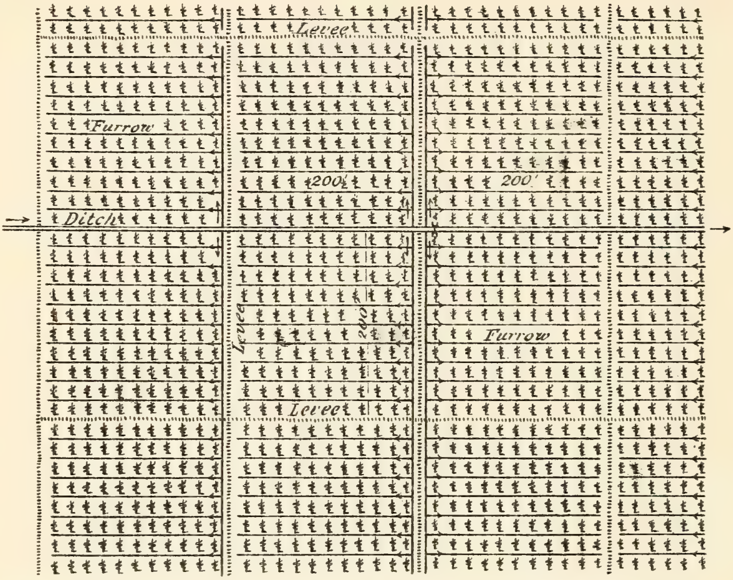


Plate 9.

Furrow Irrigation of Vineyards

in level Checks.

Fig. 1



Furrow Irrigation with Drainage.

Vineyard near Fresno.

Fig. 2.

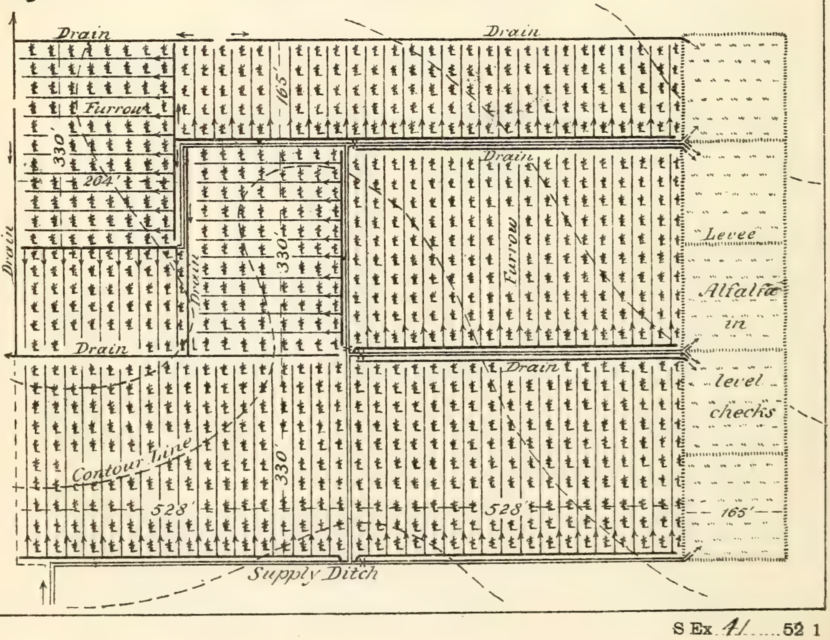


Plate 10.

Hillside Irrigation.

Furrow System.

Orchard near Porterville.

Fig. 1.

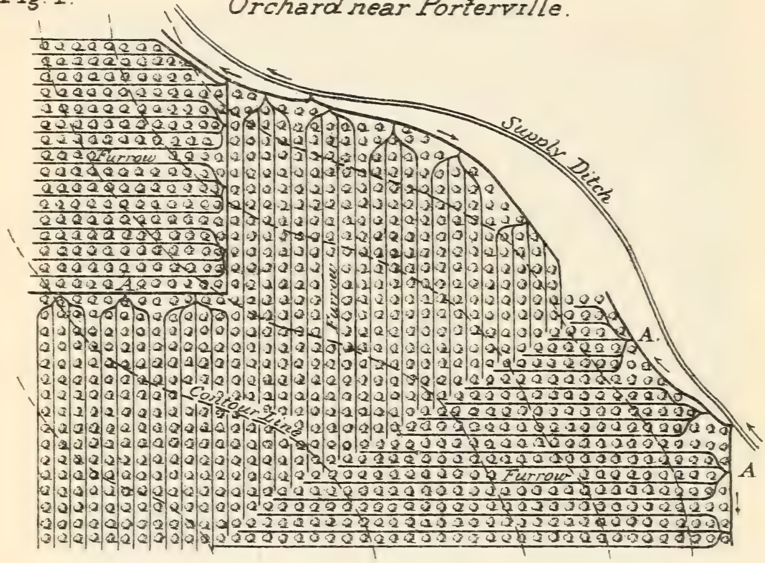


Fig. 2. Detail at A.

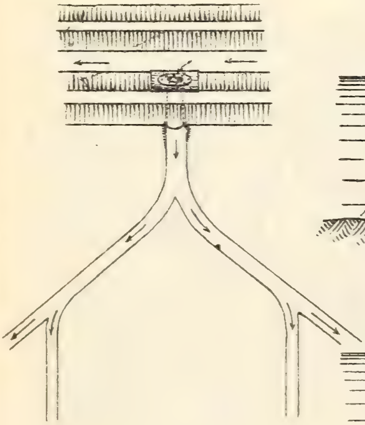
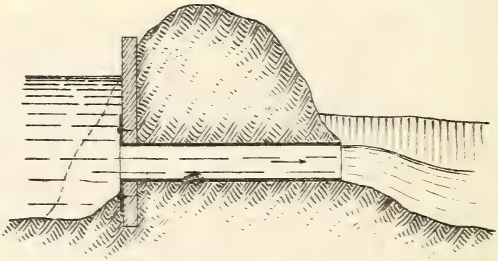


Fig. 3.



Furrow Inlet Tube.

Fig. 4.

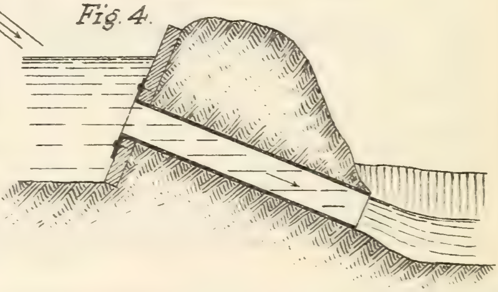


Plate 11.

Irrigation of Vegetables, Berries,

or other Crops closely set in rows.

Fig. 1. Plan.

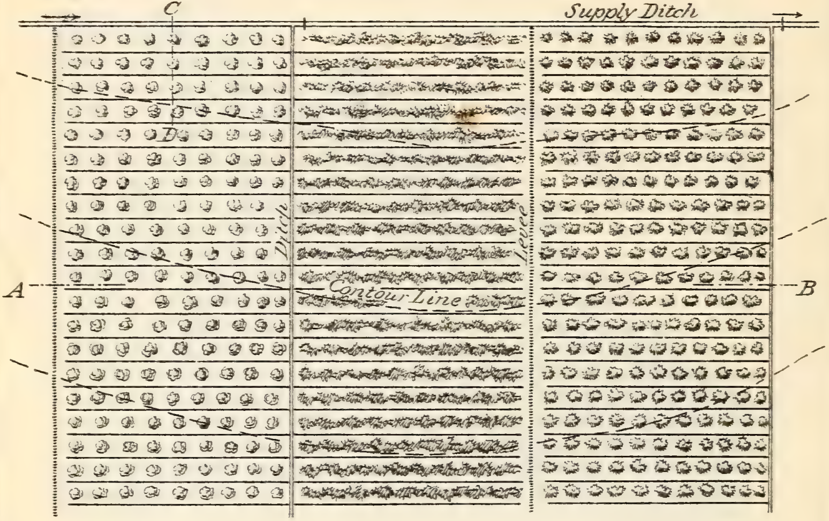


Fig. 2. *Section AB.*

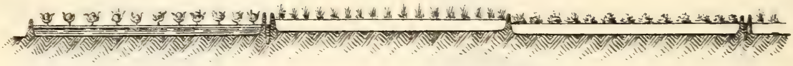


Fig. 3. *Section CD (enlarged).*

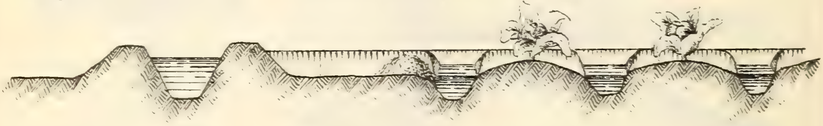
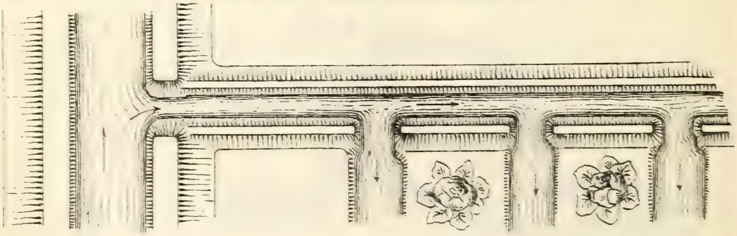


Fig. 4. *Part of Plan (enlarged).*



toward the lowest, without making provision for drainage. Ditches and furrows are arranged as indicated in Fig. 3, and great care is taken to admit no more water into each furrow than will just wet it from end to end.

FURROW IRRIGATION IN LEVELED CHECKS.

[See Fig. 1, Plate No. 9.]

When a few years ago it was feared that the ravages of the phylloxera might be extended into the vineyards of Fresno County it was deemed advisable by some vineyardists to set out all vines in checks which could be completely submerged. Fortunately such submersion to combat the phylloxera has never become necessary. But the preparation of the ground which had been made led to a new method of applying water to the land. From a supply ditch, water is admitted into a small ditch upon one side of each check, and from this small ditch it enters deep horizontal furrows, which have been drawn between each two rows of vines. As soon as water has filled all the furrows, irrigation is complete and the head of the check ditch is closed.

FURROW IRRIGATION OF VEGETABLES.

[See Plate No. 11.]

When irrigation must be more frequently repeated than in the case of orchards, vineyards, etc., as in the case of vegetables, the surface of the ground is more thoroughly prepared for the reception of water; the handling of the water is simplified. It is customary to set out most vegetables, strawberries, etc., in rows that are close together. Each row is on a ridge of ground from a few inches to a foot in height. Each row is short, varying from 5 to 20 yards. Water is supplied to a tract of vegetables in a ditch located on the highest ground. Thence at right angles to the direction of the rows of vegetables branch ditches lead through the tract past the end of the rows. Each row of vegetables and the depression between it and the next row are horizontal. Water is admitted from the small irrigating ditch to the furrow or depression between the rows to the right and left, being checked at convenient points in the irrigating ditch until all furrows above these points have been filled with water. Surplus water standing in the furrows when gates and dams have been removed will, to some extent, find its way back into the irrigating ditch; the rest finds its way into the soil. The arrangement of ditches and levees necessary to accomplish this irrigation is made fully apparent in Figs. 1, 2, 3, and 4 of Plate No. 11.

FURROW SYSTEM OF HILLSIDE IRRIGATION.

[See Plate No. 10.]

Without attempting an elaborate discussion of the best methods of irrigating hillside lands, it is desired to call attention here to a method employed by an intelligent irrigator on a moderately steep hillside set out to fruit trees a few miles above Porterville, in Tulare County. The soil was of the nature of dry bog, very dark in color, sticky when wet, cracking and crumbling when dry.

The supply ditch followed a grade line around the hillside above the orchard. At selected points it was tapped by smaller ditches, which carried the water along the hillside, below the main ditch, on a somewhat greater grade. Into the lower banks of these irrigating ditches tin tubes were imbedded, fitted into headboards resting against the inner side of the ditch bank, as shown in Figs. 2, 3, and 4 of Plate No. 10. These tubes were in use to obviate the necessity of cutting the ditch banks and to prevent the washing out of cuts in these banks, which would result if the tubes were not in use. They are only temporary features in the bank, being removed as soon as they are no longer required at any particular point.

These tubes can be made of any thin material, like galvanized iron or tin, which can easily be bent into the desired form. The great advantage of using some contrivance similar to these tubes is the ease with which the amount of water taken from the ditch at any point can thereby be regulated.

The water delivered through each tube was subdivided into three or four furrows, drawn as indicated in Fig. 1, between each two rows of trees, through a well-plowed and well-pulverized soil. One attendant, without any hard labor, could keep small streams trickling down thirty furrows at one time. After irrigation the entire surface layer of the soil of the orchard was wet, and much water had penetrated into the substrata of soil.

IRRIGATION FROM SUB-SURFACE CONDUITS.

[See Plates Nos. 12 and 13.]

This method of applying water to land has not been as satisfactory as it was hoped by its friends that it would be, but having been introduced in some localities on a large scale it can not here be passed without a notice.

The intent of this method of irrigation is to supply a moderate quantity of water directly to those parts of the soil where moisture is needed without wetting the surface of the ground. Thereby it was hoped to economize water, to greatly simplify its distribution and control, to cheapen irrigation, and to avoid the baking of soil and the necessity of breaking up its surface after each application of water.

The system of sub irrigation which has generally found favor is illustrated on Plates Nos. 12 and 13. It is essentially a pipe system. Water is distributed to all parts of the land to be irrigated in cement pipes, from which it escapes through perforated plugs of wood. It is admitted into pipes under a low pressure, sufficient to insure the escape of some water even in the highest parts of the land to be irrigated. The system is applicable only to smooth surfaced tracts having but a slight slope.

The final distributing pipes are constructed by means of a peculiar machine. They are made in place and are continuous. The diameter of their bore is 2 inches. At intervals corresponding to the distance between trees or vines they are perforated from above and a wooden plug with a hole lengthwise through it is inserted in the perforation. This plug is protected by means of a hollow cap or earth guard resting loosely upon the pipe over it. (See Figs. 9 and 10, Plate No. 13.) The pipe is placed 20 inches or more below the surface of the ground so as not to interfere with plowing, cultivating, etc. Water is conducted to the 2-inch pipes, which may be laid between each two rows, if rows be far apart, as in the case of trees, or between alternate rows, if they be close together, as in the case of vines, by means of a system of 6-inch

Plate 12.

Sub-Irrigation.

Fig. 1. General Plan for Vineyard and Orchard.

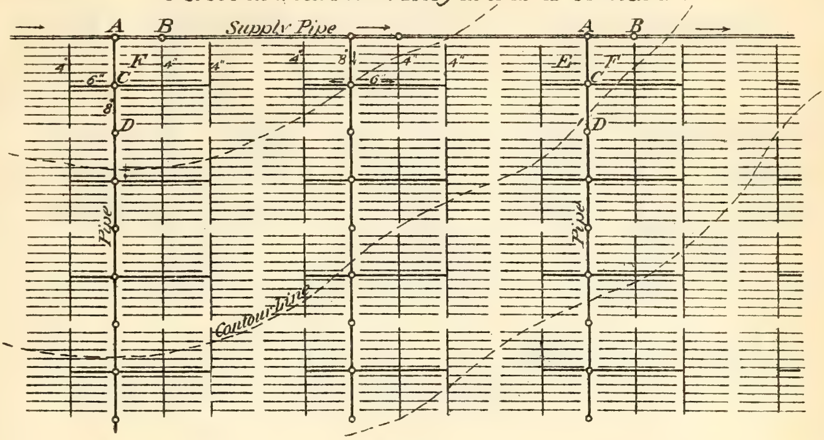


Fig 2. Plan of Block "E" – Vineyard.

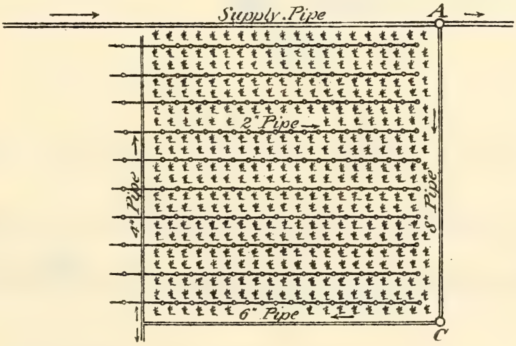


Fig. 3. Plan of Block "F" – Orchard.

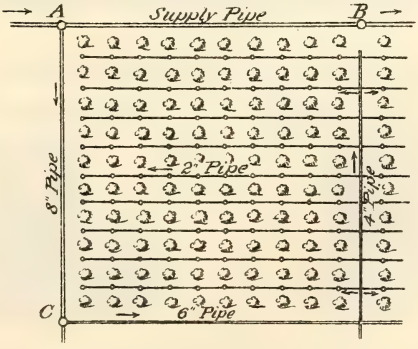


Plate 13.

Sub-Irrigation

Details.

Fig. 1. Section GH.

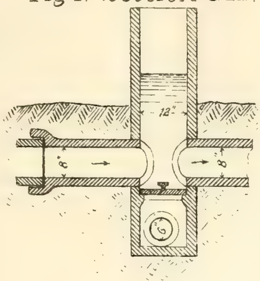


Fig. 3. Section IJ.

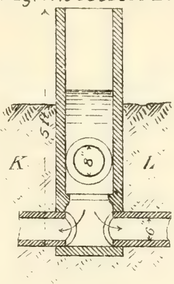
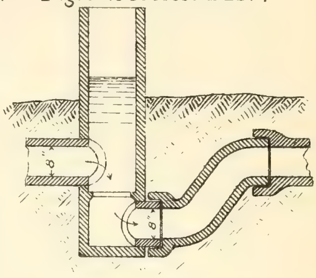


Fig. 5. Section MN.



Hydrant at C.

Hydrant at B and D.

Fig. 2. Plan.

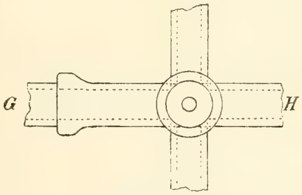


Fig. 4. Section KL.

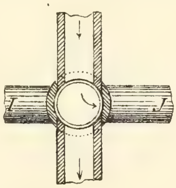


Fig. 6. Plan.

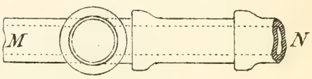


Fig. 7. Section and Elevation of 2 inch Pipe.

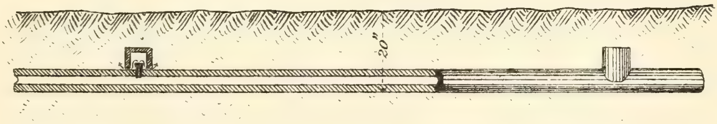
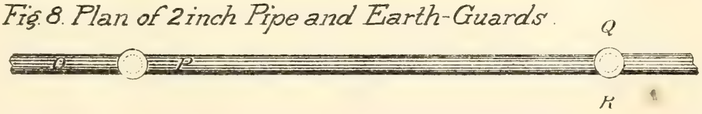


Fig. 8. Plan of 2 inch Pipe and Earth-Guards.



Sections of Earth-Guard (enlarged).

Fig. 9. Section OP.

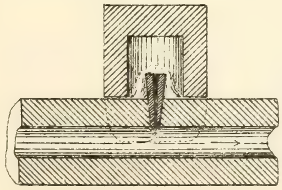


Fig. 10. Section QR.

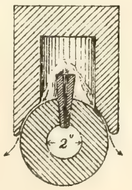


Plate 14.

Pump Irrigation.

James Rutter, Florin, Sacramento Co.

Fig. 1. Section AB.

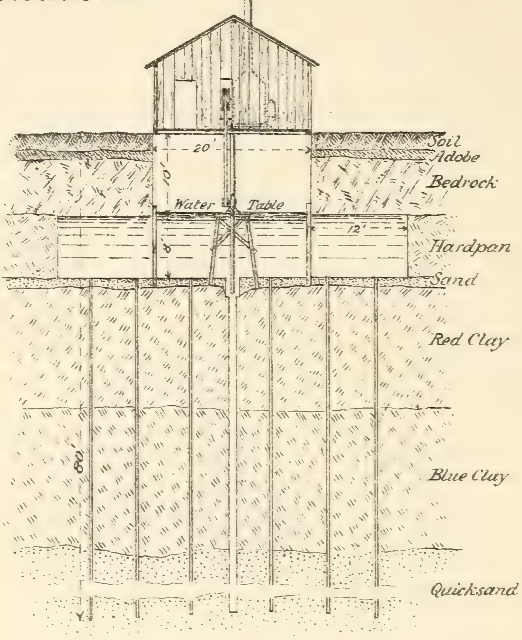
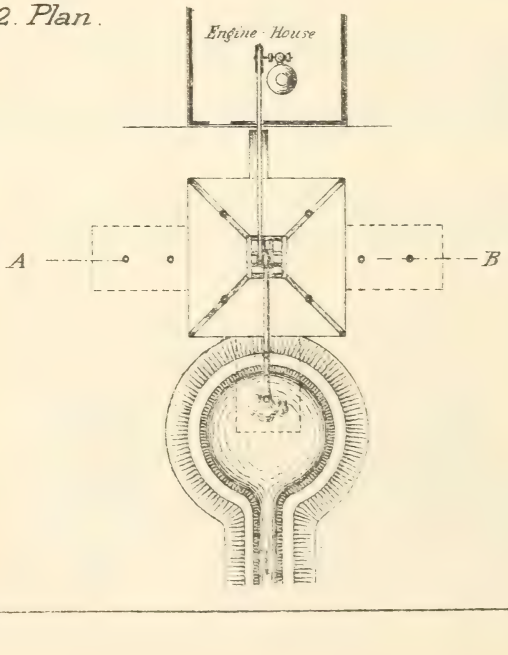


Fig. 2. Plan.



and 4-inch pipes, which in turn receive water from a main supply pipe, generally about 8 inches in diameter.

The illustrations given on the two plates already referred to show a possible arrangement of the pipes, etc., for the irrigation of vineyard and orchard land. In Fig. 1, Plate No. 12, an 8-inch supply pipe follows the line AA BB. From it branch off in the direction ACD 8-inch pipes, which convey all the water in turn to the several tracts to be irrigated. From the branch pipe lines ACD, at the points C, 6-inch pipe lines carry off the water and distribute it to a number of 4-inch pipes, and these in turn to the final 2-inch pipes.

At all points where 8-inch and 6-inch pipes branch, so-called hydrants are introduced as shown in Figs. 1, 2, 3, 4, 5, and 6, by means of which the water may be shut off from one line or the other of pipe. The hydrant represented in Figs. 5 and 6 illustrates the means of checking the flow of water in a pipe main. In the drawing the pipe is represented as open. It can be closed by inserting a disk and resting the same on the projecting rim around the hydrant below the mouth of the inlet pipe and above the head of the outlet pipe. The hydrant shown in Figs. 1 to 4 will enable the closing of the 6-inch pipe system from the 8-inch line, but it does not enable a closing of the 8-inch line and a forcing of all water into the 6-inch pipes.

When water is to be supplied to any part of a vineyard or orchard, as, for instance, to the six blocks commanded by the two 6-inch pipes which leave the 8-inch pipe line at C, then it is first necessary to close the hydrants at B and D. All water arriving at A must flow into the pipe toward C, and thence into the 6-inch pipes, 4-inch, and 2-inch pipes until they are all full. It will escape from the plugs into the ground and must be supplied fast enough to stand in the hydrants everywhere above the highest parts of the 2-inch pipe system, so that there may be no doubt that water is escaping from every plug in the tract covered by the 2-inch pipe system. As soon as irrigation from this system of pipes is complete the 6-inch pipes in the hydrant C are closed off and another set of pipes is brought into use.

Under favorable conditions it will cost about $50 per acre to prepare ground for irrigation by this method. The roots of trees and plants will, notwithstanding every precaution to prevent it, find their way into the lines of pipes at exposed points and may seriously interfere with a successful irrigation.

Until irrigators are required to be very much more economical in the use of water for irrigation than at present, the matter of expense alone will interfere with any extended use of this system of irrigation.

EXAMPLES OF PUMP IRRIGATION.

On Plates 14 and 15 are shown a few examples of irrigation with water secured by pumping. The most interesting of the several examples is that showing the arrangement of a reservoir chamber and eleven wells which supply water to it, as carried out by Mr. James Rutter, at Florin, Sacramento County. From a large pit 25 feet square and 18 feet in depth, he drove three short tunnels into the hardpan, which was sufficiently firm to stand without lining. When the reservoir space had thus been made sufficiently large (about 5,000 cubic feet) eleven wells were bored to depths of about 80 feet. The central well has a 10-inch bore; the others are 4-inch wells. These wells supply water to the reservoir chamber, in which it rises to within 10 feet of the ground's surface. It is drawn from this chamber by means of a centrifugal pump, which when run at full speed lowers the water table 8 feet in about five hours. About 80 acres are irrigated with water thus pumped on the Rutter place.

L. A. Oppenheim, Dr. W. A. Hughson, and others, near Florin, secure water for irrigation in the same way as Mr. Rutter, though generally the reservoir pit is circular in form, and one boring is relied upon to supply water to it. (See Fig. I, Plate No. 15.)

W. B. Blowers, near Woodland, Yolo County, draws water from a large circular well or cistern 18 feet in diameter, lined with brick, which was sunk into a layer of gravel. Water is elevated by means of a centrifugal pump. (See Plate 15.)

ARTESIAN WATERS OF SAN JOAQUIN VALLEY.

In the foregoing pages reference has several times been made to the artesian wells in San Joaquin Valley. The results of my examination of nearly 300 of these wells, which was made for the State engineer department, have been presented in tabulated form in the book published by that department, entitled "Physical Data, etc."*

The source of supply for the wells of this valley is at the base of the Sierra Nevada, where waters sink from the rivers into layers of sand, which lie between layers of clay. This source of supply and the stratification of the valley as revealed by borings near Tulare Lake is shown on Plate 16.

A typical boring is shown on Plate 17, Fig. III, which shows the stratification as reported by the well-borer. In Figs. I and II on the same plate the arrangement of the reservoir or pond which is connected with the same well is shown.

The casing ordinarily used for artesian wells is of the double sheet iron type (Fig. IV), rarely of the screw joint pattern. (Fig. V.)

Loss of water from ordinary casing is illustrated in Figs. VII and VIII of Plate 17. The former represents the arrangement of a tank receiving water from a well on Kern Island. When it was found that much water was lost a box was sunk into the ground, and the leakage from three joints was found to be as much as the flow into the main tank. This leakage was brought to the surface by the box contrivance shown in the illustration.

Fig. VIII illustrates the arrangement at the artesian well which supplies water to Hills Ferry, Merced County. Leakage above the hardpan is sufficient to saturate the heavy clay soil, and to keep a small pond full of water.

Fig. IX illustrates the arrangement of the Cutler Salmon well about 8 miles southeast of Stockton. The inner casing (4 inches) supplies a large volume of gas, which rises with water that is strongly alkaline from a depth of 1,250 feet. The outer casing supplies potable water from a depth of 844 feet. The gas is used in the kitchen and throughout the dwelling for heating and lighting purposes. The potable water is conveyed to various points about the Salmon place in pipes. The saline water commingled with the other has a temperature of about 80°, and is used in public baths.

WATER MEASUREMENTS.

The necessity of delivering water to irrigators by measurement is beginning to be recognized. A unit of measuremnet is essential, and it will not be long before the "cubic foot per second," which is a defi-

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*See Physical Data: Wm. Ham Hall, State Engineer, pp. 480–527.

Pump Irrigation.

L. A. Oppenheim, Florin, Sacramento Co.

Fig. 1. Section AB.

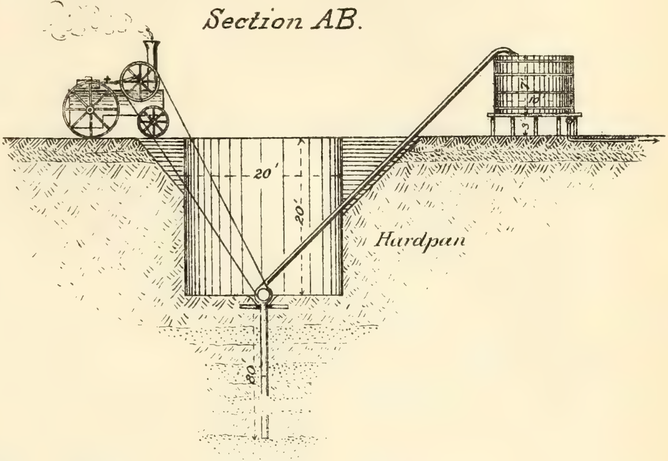
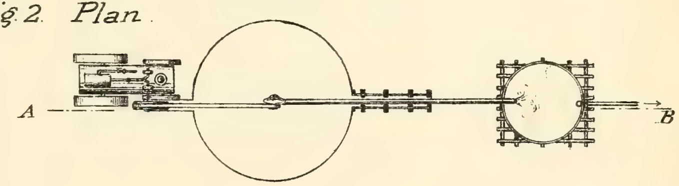


Fig. 2. Plan.



W. B. Blowers, Woodland, Yolo Co.

Fig. 3. Section AB.

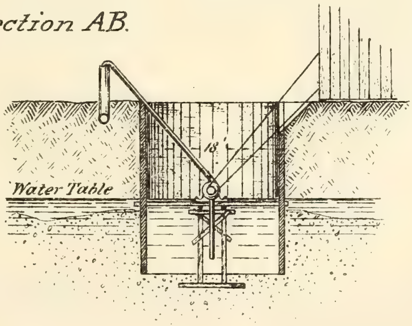


Fig. 4. Plan.

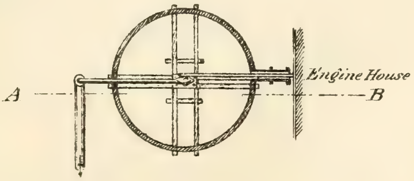


Plate 16.

Stratification of San Joaquin Valley.

Fig. 1.

Section from NE to SW, through Tulare.

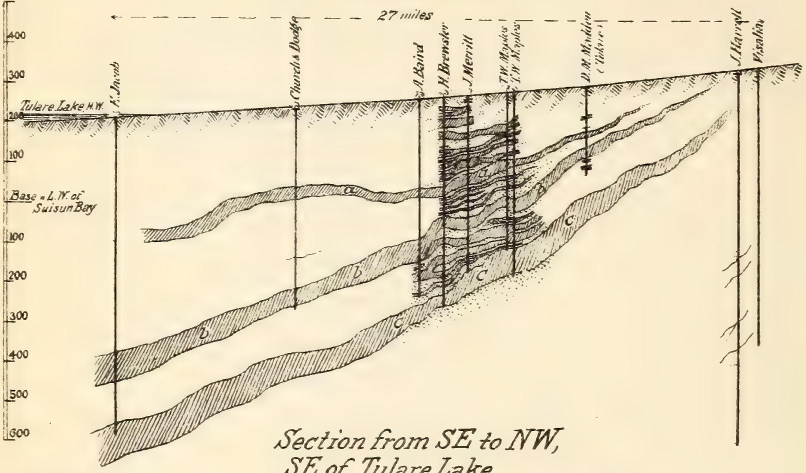


Fig. 2

Section from SE to NW, SE of Tulare Lake.

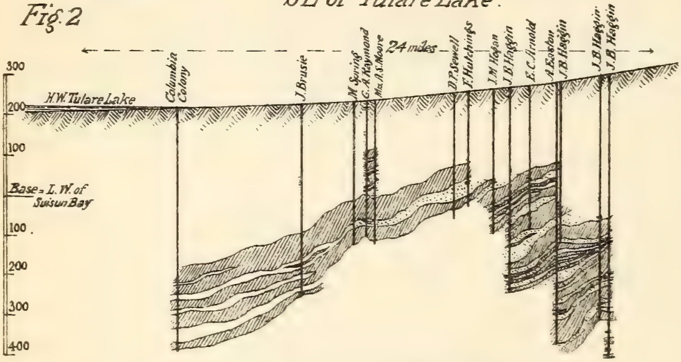
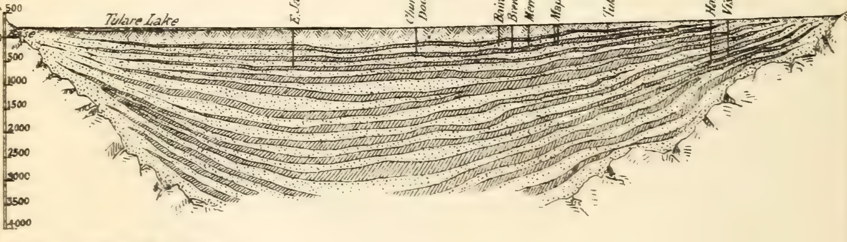


Fig. 3.

Ideal Cross Section of San Joaquin Valley through Tulare Lake, showing Stratification.



nite quantity, will have superseded the "miner's inch" (which is no unit and defines a method rather than a measure) throughout California.

There have been but few satisfactory measuring boxes constructed in California, and in most cases at the present time water, when measured at all, flows through orifices under pressure. This method of measurement is always unsatisfactory, and ought whenever possible to be exchanged for weir measurement. I have endeavored to plan a measuring box which is adapted for use under conditions of water delivery as they generally prevail on the larger irrigation works in California, and have made a weir with clear overfall the basis of the water measurement. The contrivance is illustrated on Plate No. 18, and is shown in connection with a "checkweir" or "drop," as such structures are commonly arranged in the central portions of this State. The main canal in the diagrams is supposed to have a width of 24 feet; it may be of any width.

Its flow is checked by means of the gates G G, which are supposed to be constructed on the principle of loose flash boards, whose ends slide in vertical grooves along guide posts. By means of these gates, which might be arranged in any other manner, the water surface of the canal above the weir is made to rise to about 1 foot above the water surface, just below the checkweir. One foot fall from upper water to lower water in the main canal is not necessary, but is desirable and should never be less than one-half foot. Through the gate H enough water is admitted into the receiving box I I to keep the samefull to the crest of the overfall edge J J. This overfall edge may be made movable by closing the spaces between the posts on the side of the receiving box by means of loose boards, of which the upper one in each case is provided with a sharp edge, preferably of thin wrought iron.

From the receiving box water is admitted through a gate, K, susceptible of close adjustment (submerged orifice) to the measuring box L L, whence it flows over the weir W into the branch ditch. At a convenient point in the measuring box a graduated scale is securely fastened to the side of the box, on which the elevation of the water surface in the measuring box indicates at once the number of cubic feet per second which are passing over the weir.

The weir for use in this box may be constructed according to any approved pattern. It should have a sharp edge, and may have vertical sides or inclined sides to compensate for contraction. It can be made long or short, but should generally be about 2 feet shorter than the width of the box L L. The length of the crest of the weir should be adapted to the water quantity ordinarily required to be passed over it.

With this measuring box (or module) the requirements prescribed by Prof. L. G. Carpenter, of Colorado, and other eminent hydraulic experts can readily be fulfilled.

The quantity of water delivered by this measuring box in a given time is a definite quantity, and is measured with reasonable accuracy if proper attention has been paid to the conditions which should prevail and are prescribed by hydraulicians to secure correct weir measurement. The crest of the weir must be horizontal. Air must have free access under the sheet of falling water. Weir sides should be at least as far from the sides of the measuring box as the maximum depth of water intended to be delivered over the weir. Weir sides, when water quantity is to be determined by length of weir without corrections for contraction, should be inclined one-fourth horizontal to one vertical. The crest of the weir and the sides must have sharp edges, which should be in the same vertical plane.

The channel of approach, that is, the water way between bottom and sides of the measuring box, should be ample to reduce the velocity of approach to less than one-half foot per second, when the weir is taxed to its intended maximum capacity. The water must have a free outfall; that is, the water surface below the weir should be so much lower than the weir crest that its influence upon the shape of the surface of the overfalling sheet of water is not readily perceptible.

The measurement of water passing over the weir is perfectly reliable when, in addition to the above requirements, the following conditions prevail:

(1) When water flows over the weir crest with a depth of 0.25 to 2 feet.

(2) When the depth of water on the weir is less than one-fourth the length of the weir.

(3) When the height of the weir crest above the floor of the measuring box is at least twice the depth of water on the weir.

When these three conditions do not prevail, that is to say, when a very small quantity of water is delivered over a large weir, or when a weir is taxed beyond the maximum flow for which it was intended, then results are only approximate.

There are comparatively few cases where ample fall from main canal to the distributing canal is not available for the introduction of a measuring box, as above described, and in the main canals the necessary fall of one-half to 1 foot is always available, except occasionally in the case of main canals, which have been carefully constructed to grade lines. In these a backing up of water for one-half to 1 foot is always permissable, except when the canal is flowing at full capacity, and then water may be admitted direct from the main canal through the gate H into the measuring box. At such times water is plentiful, light fluctuations in the elevation of the water surface above the weir are least objectionable, and the canal water surface has greater stability at that stage than at any other.

In this measuring box an orifice under pressure may be substituted for the weir, but it will not be found satisfactory except where prejudice, as the result of long-established custom, prevails in favor of a delivery of water by "miner's inches."

Plate 17.

Artesian Wells in San Joaquin Valley.

Fig. 1

Ground Plan of Artesian Well and Reservoir

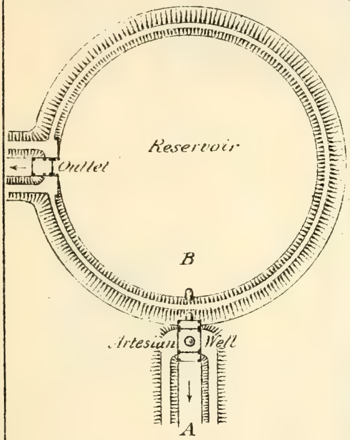


Fig. 3.

Raymond Well

KERN COUNTY

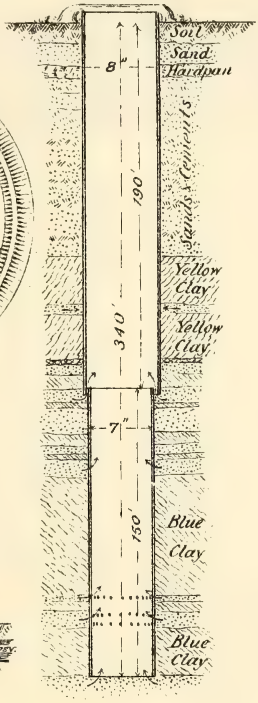


Fig. 4

Ordinary Casing.

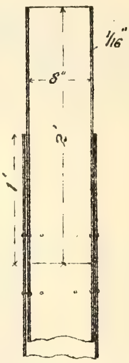


Fig. 5.

Screw-Joint Casing.

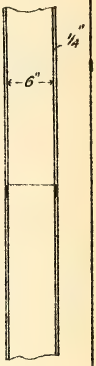


Fig. 6.

Fig. 2. Section AB.

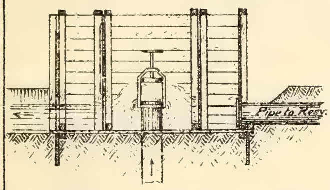


Fig. 7.

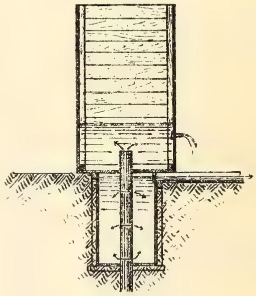


Fig. 9.

Cutler Salmon's Well near Stockton.

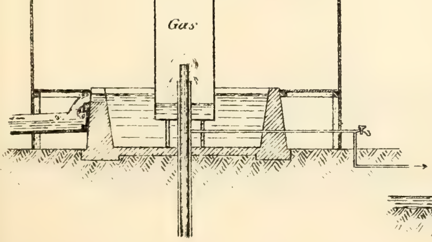


Fig. 8. Harris' Well at Hills Ferry.

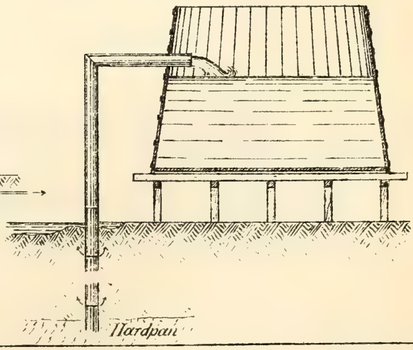


Plate 18.

Measuring Box
by
C. E. Grunsky.

Fig. 1. Section AB.

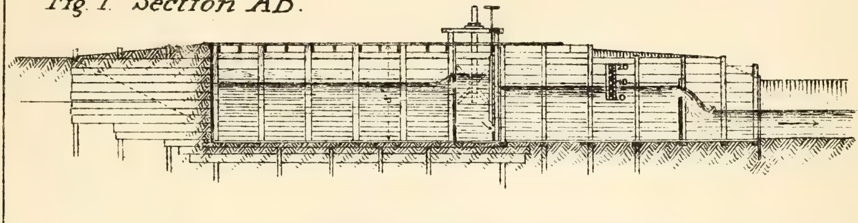


Fig. 2. Plan.

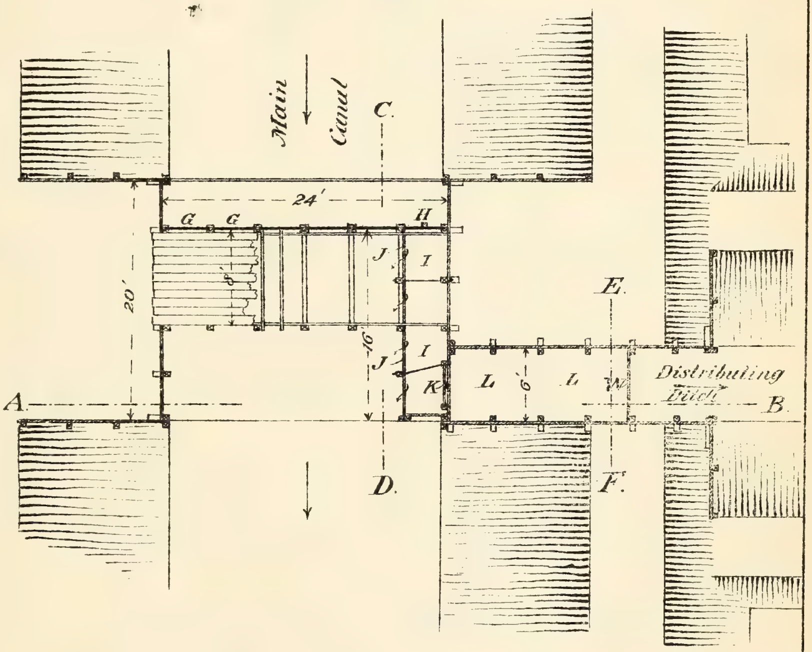


Fig. 3. Section CD.

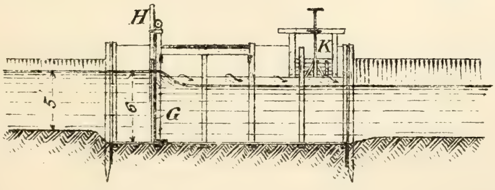
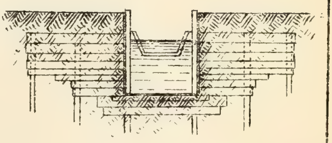


Fig. 4. Section EF.



CULTIVATION OF THE SOIL BY MEANS OF IRRIGATION IN SOME OF THE SOUTHERN STATES.

LOUISIANA.

Considerable discussion has been had in various associations over the value and necessity of irrigating the important sugar cane and other crops. Rice, one of the staples of Louisiana, is of course cultivated by means of irrigation, and it is the example it always offers that induces other planters to turn to this source of security when the heated term so seriously affects the welfare of their valuable crops. The idea underlying present debate is forcibly expressed by the Louisiana (New Orleans) Planter of October 10, 1891, as follows:

> As we progress in our studies in the use of water for the forcing of plant life we shall doubtless find that we can aid or modify the influences of nature readily and effectively by irrigation. Our months of highest temperature, July and August, are of course those most conducive to active plant life, and the proper supply of water is an essential of such life.
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> As against the conclusion founded upon seemingly limited data, the year of 1889 stands out strongly. With an August rainfall in New Orleans of above the average, omitting the abnormal one of 1888, yet the crop was a short crop, and was caused by the self-evident drought that began early in that year and continued throughout the year. With a largely increased acreage the crop fell off some 20,000 tons, notwithstanding the record shows adequate rainfall, or an excess, in August and September.
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> We present these studies not claiming that any sound conclusions can be based thereon, but to create an interest in this line of inquiiy, it seeming evident that our cane crop is now more dependent upon the supply of water for vegetation than upon that of temperature during the summer months, the necessary temperature being assured by the records, while the rainfall is the variable factor. To secure adequate moisture we shall probably have to call in the art of irrigation to supplement the deficiencies of nature.

Papers of value were prepared and read before the Audubon Agricultural Associations of Louisiana, during the year 1891, which present in so intelligent a form the reasons for an interest there in irrigation, that it is deemed proper to insert some extracts from them in this place. At the Audubon Association meeting held in June, 1891, one of the essayists read a paper in which the following points occur:

> Nothing is better for pastures or for the hay crop than irrigation; but for melons, squash, cucumbers, cabbages, and other vegetables, where irrigation or submerging during the growing season may be extremely dangerous, nay, fatal, I have used the sprinkling can with great advantage. Small wells are dug in the ditches, say every one-fourth of an acre, in order to have the water supply close at hand. One small boy can easily keep ahead of two live men whose duty it is to immediately cover the moist ground by pulling dirt to the plants; by this means I have watered from morning to night with great benefit to the plants; but, on a large scale, I would advise a system of windmills supplied with sufficient cisterns or tanks properly elevated so that sprinkling carts could economically obtain the water; these carts could be so arranged that three or four rows could be sprinkled at one time, and if care be taken to cover up the moist dirt immediately by means of rotary hoes or other implements, watering can be continued with impunity during the hottest and driest parts of the day; for if this is not done the moisture obtained at so great an expense is soon absorbed by

the rays of the sun, and the ground becomes so hot that the tender roots of the plants become scalded.

Another plan that has been tried and given satisfaction is to fill small wells situated in the ditches at regular distances (say the ditches themselves could be filled with water obtained by means of a syphon or water pipe), then a portable steam pump drawn by two mules can water or sprinkle one-half an acre on each side of the ditch, and if care be taken to immediately cover up this moist ditch, acres upon acres could be sprinkled by means of such an apparatus in a day. In my opinion sprinkling is preferable to irrigation proper, for it imitates in a certain manner the rain, for there is no doubt of the fact that when water is aërified it becomes charged with more elements of fertility, and is better not only for the vegetable but also for the animal creation.

Another system that has many advocates is a system of irrigation and tile drains combined.

Such system of watering would prove of incalculable benefit to the truck farmer, for many vegetables are planted, grown, and are harvested in six to eight weeks' time; a drought of three or four weeks must necessarily diminish our production one-half, making our profits considerably small, and, as we farm for profit, it behooves us to lessen as much as possible the danger incidental to atmospheric changes.

Mr. Gus. V. Soniat read a paper of considerable value;* he presented concisely the leading facts in regard to the world-wide use of irrigation, and then states that—

Irrigation is an indispensable adjunct to cultivation in a dry climate and a sandy soil, where the ground water is far from the surface, for water is essential to vegetation; deep-rooted plants find their supply in the low strata of the earth, but for superficial feeders, unless the rainfall be plentiful and come at needed times, the plants soon shrivel, die, and then decay for want of this necessary element, and no wonder, for the majority of plants need moisture, heat, soluble soils, air, and light.

"Out of these five necessary elements, three," says Mr. Soniat, "have a preponderance of water." He continued, as follows:

Whenever the ground water falls to 13 or 16 per cent the majority of plants will suffer, unless the hydrostatic conditions of the air be exceedingly favorable. * * * Water then must be supplied in some manner, shape, or form, and a proper relative between the five necessary elements above-mentioned must be maintained. * * * The necessity, then, of ground water must be apparent, and to supply it we must by artificial means when natural ones fail. According to Storer, the rainfall is not sufficient to supply the evaporation caused by the sun; even here in Louisiana, with an annual rainfall of about 60 to 70 inches, how much of this water is utilized by the growing plants? I dare say a very small proportion, for we are in the greatest hurry to send it to the swamps as quickly as possible in our open ditches; and we call this drainage? Yes, a drain is upon our superficial soil, and it is a wonder to-day that the vegetable portion is not completely washed away.

The fact seems incredible, but I have seen dry land turned over by a two-mule plow immediately after a 3½ inch rainfall, thus showing conclusively the wanton waste of this fluid. Tile drains have partially remedied this evil, and have done wonders in augmenting thereby the vegetable power of Louisiana clay soils, rendering them nearly as porous and consequently as great retainers of humidity as our sandy loams. But how greatly could we increase this were we to utilize this vast amount of moisture and give it to the plants at different times; an acre of our land would be worth fully twice as much as an acre of northern lands; for if we multiply our average temperature by our annual rainfall (this is an old French rule), and make a comparison with theirs we find that we more than double their vegetative power, Our annual rainfall is about 60 or 70 inches, and our average temperature about 70° F., whilst in many States the rainfall varies from 40 to 50 inches and their average temperature 40° to 60° F.; yet, strange to say, some Northern and Western farmers are able to compete with us in certain vegetable productions. And why? Simply because either by artificial or natural means a better relation between heat and humidity is maintained during the growing season of the plants. * * * We irrigate and irrigate with a vengeance, not only our rice fields but often the cane fields of our neighbors, to their detriment and annoyance. But few cane farmers are aware of the fact that a rice planter is often a great benefit to the neighboring crop of cane for the following reasons:

(1) By filtration through the soil the necessary ground water is supplied to the canes.

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* On the Possibilities of Irrigation in Louisiana, Audubon Association.

(2) The rainfall in any locality is greatly augmented by the rice planter, for "water will draw water," as the old saying goes, for the simple reason that hot vapors passing over a water surface, meeting relatively cool vapors constantly arising from the said surface, become condensed and fall in the form of rain, not only for the benefit of the rice field, but also for that of the whole neighborhood. The contrary is the reason why there is no rainfall in the desert, for the dry heat constantly arising repels and keeps in a vaporous state the moisture that may be floating in the atmosphere.

Irrigation, then, when properly understood, is a source of health and wealth, but when improperly used breeds pestilence and death, misery and all its concomitant evils; witness the evils occasioned yearly by badly-constructed pipes or flumes, etc. Our rice planters owe their wealth and success to the proper use of irrigation, for by this means the expenses have been considerably lessened and the yield greatly augmented over the dry culture, but constant care and attention are required for success; if, perchance, they irrigate at inopportune times and are unable to quickly drain their rice fields the stand of rice is endangered; or if they maintain too great a supply of water when the plant is young it can not tiller and becomes too slender to resist the storms of summer. Drainage and irrigation, then, must follow one another to insure success in all crops; in fact, the oftener we water and drain young plants the better our crops will be, for if we observe the root development of plants we will find that the roots are often double the length of stalks when the plants are young, but afterwards the stalks become twice the height of the roots. It stands, then, to reason that one watering or irrigation in time may be worth to the roots (hence to the plants) two or three later on. This is the reason why we must thoroughly prepare our soils before the planting of any crop and work the same in its early infancy in order that the young and tender roots may not be obstructed or impaired in the least, for if they are checked in the beginning of their career the plants become stunted and refuse to grow or develop as the farmer desires. Why, then, are the farmers in this section so backward in utilizing this great river that holds in solution yearly more tons for of fertilizers than the boasted guano beds of South America? Why, then, have the progressive cane planters not imitated the cane farmers of India, who irrigate regularly their canes?

Because success has not placed her stamp upon the ventures of those who have had the audacity to try this on our soils. May I be bold enough to point out the causes of their failure? Perhaps then a remedy may be found.

(1) Irrigation has been tried in the spring, when the river water is from 15 to 20 degrees colder than the soil, thereby injuring by such a sudden transition the tender cane roots.

(2) Because it has been tried in the summer in the heat of the day instead of night, thus scalding the roots.

(3) Because it has been tried to flood from the ditches by forcing the water to rise on the land, thereby expelling the air contained in the soil, stopping the drainage conduits and packing or puddling our clay lands.

(4) Because a drought in lower Louisiana rarely exceeds four or six weeks, or barely one-eighth of the growing time of cane, which is not enough to materially injure the growth if properly worked and highly fertilized; but when a drought lasts as it has lasted this year our cane crop can easily be reduced one-third or one-fourth. The only way of successfully irrigating cane or corn is to allow a certain amount of water to course down the water furrows late in the evening or during the night; for if we flood the entire plat of cane or corn, the sudden transition from excessive dryness to excessive moisture will certainly injure the roots that are then deep in the soil, and compel the plants to form new roots near the surface, and lose thereby valuable time to the detriment of its growth. When we flood the entire land the effect is as bad or worse than when a flooding rain comes. * * * The greatest drawback in cane culture is not generally the want of rain during the growing season, but to its absence during the months of October and November—the time of preserving our seed-cane. We are then in such a hurry to prepare for the grinding season; we are in so great a dread of Jack Frost that from the fear of Scylla we fall into Charybdis; from the fear of losing a few top eyes we run a greater risk of losing all by dry rot; but some planters now prefer to wait for a light frost before windrowing, claiming that the canes are hardy, and are therefore better able to withstand the winter. But the reasons, I think, that can be given to the better preservation of such seed canes are:

First. The later we put our seed cane in windrows the less time it has to spoil; hence the better it keeps.

Second. Generally, after a few light frosts, we have a rain, for the reason that the vapors constantly arising from the Gulf of Mexico, meeting the cold currents of air that has given us these frosts, become condensed and thereby produce rain or enough moisture to preserve our seed cane. But generally we windrow in a drought and trust to luck; nine times out of ten luck is against us, when a little pluck or energy would save us; we are, as Tantalus, surrounded by water and we perish with thirst. We are encircled by plenty, and we die of want. What a shame for man's intelligence, and what a shame must I have to acknowledge that I have suffered from the same cause when the remedy is so simple—irrigation. Two days' pumping with a good pump could easily moisten 100 acres of windrow or fall plant, at a nominal cost per acre, and forever banish this evil. We may suffer from wet rot, if not properly drained, but from dry rot, never.

Irrigation has been used with the greatest advantage in the planting of corn, peas, sweet potatoes, cabbage, etc. In a drought the rule to be followed is:

First, irrigate thoroughly; then drain. As soon as the ground has been dried sufficiently, planting can be done with dispatch, and failure is impossible. To prevent rust in oats I know nothing superior to irrrigation during a dry spell.

At a meeting of the same association June 20, 1891, Mr. J. Y. Gilmore read a paper in which occurs the following suggestions:

In Louisiana the possibilities of irrigation are great; no doubt far beyond the comprehension of the most sanguine of us. While we have an annual rainfall of more than double the average throughout the United States, yet we are subject to the most severe drought, especially in spring time, when crops most need moisture. Hence in the near future irrigation will become common here. Along our water courses in alluvial Louisiana the lands are comparatively level, with a gradual slope from the streams. Hence, with a vast and inexhaustible water supply to draw from, and but little labor requisite to conduct it wherever we choose, in a short time every crop will be thus aided, for science has shown us that it is by liquid absorption that all plants take nourishment. It is no exaggeration to say that when our planters have perfect control (as they may) of both drainage and irrigation, the productiveness of our soil will be doubled. Thus a greater diversity of crops will be the result, for it has been proven that when conditions of the soil can be controlled vegetable culture is more profitable in Louisiana than any where else, because of climatic advantages.

Orange culture will be wonderfully stimulated by proper irrigation, for the losses from drought on newly planted groves are far greater than from cold. Then, too, there is no doubt that when severe colds are expected a proper water treatment will save many trees, which otherwise would be severely hurt by ice.

Drainage and irrigation are twin sisters, and without a perfect system of drainage irrigation is not practicable. Hence, subirrigation promises to become the popular method, for when the ground is properly tiled it gives perfect drainage, and when necessary (not so frequently, however, as on untiled ground), the water can be forced through the pipes, whose outlets being stopped will cause the water to rise to any height desirable, as was done recently so successfully by Dr. Stubbs at this station. Thus cultivation can be continuous, which would not be the case with surface irrigation. However, in subirrigation great care will have to be taken not to allow the water to stand too long in the soil, which would exclude the air as well as tend to fill the tile with sediment, but it should be drawn immediately after reaching the height desired, when the air will follow the receding water and leave the land in a highly porous condition, and at the same time avoid the baking of the surface, as when irrigated from above. However, Mr. James D. Houston, on his Ben Hur plantation, in the parish of East Baton Rouge, has this season irrigated his cane most successively by the open ditch system.

When we consider that nature has given us such a bounteous store of water to be had simply by asking, it is a shame that any crop in our alluvial soils should suffer from droughts. Those who urge the objection that our waters are too cold are either unaware or unmindful that in Colorado, New Mexico, and elsewhere in the West, where all crops are made by irrigation, the waters are most of icy coldness, being from the melting snows of the mountains, and so cold that no fish except the mountain trout can live therein. Then, too, when it is remembered that these expensive canals are constructed to carry water along ditches, it should make us more highly appreciative of nature's kindness here and determine us at an early day to bring our land to the highest state of culture by a proper system of irrigation and drainage.

Dr. W. C. Stubbs, of Audubon Park and New Orleans, read before the Sugar Planters' Association of Louisiana a valuable paper on the need of water management and distribution for the security of the sugar-cane crop, which deserves to be reproduced in full.* Those portions only which bear directly on the cultivation of Louisiana staples by means of irrigation are, however, presented. Dr. Stubbs opens his important paper by asking:

Shall we irrigate in South Louisiana, a country almost submerged beneath water and which is known to have a very heavy rainfall?

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* "Sugar Cane Irrigation," Louisiana Planter and Sugar Manufacturer, New Orleans, October 17, 1891.

He continued interrogatively at some length and then said:

> The sugar planter · · · is particularly interested in every obstacle to maximum production. · · · He has realized that a full crop is rarely obtained oftener than once in twenty years, and that of the failures fully 80 per cent are assignable directly to drought.

The questions thus asked, Dr. Stubbs answers himself in the statement that "irrigation eliminates the great element of chance from our farming operations, and good drainage makes the planter nearly independent of the freaks and idiosyncrasies of the weather, is the concurrent verdict of those who practice this art." The doctor proceeded to give a succinct account of irrigation as practiced in other times as well as in our own generation, and then continues:

> The short history given will show, first, that irrigation is not new and untried; second, that its beneficial results are so apparent to those who have practiced it that immense sums have been invested in permanent works; and, third, that irrigated districts yield the largest productions with the greatest profits. Just here permit a digression. The time was when the country east of the Mississippi, with its large annual rainfall, heavily wooded forests, and rich sugar soils, reveled in the conceit that it alone was the agricultural portion of the United States, and that their products would always be in demand in the less favored claims of the extreme west, where only mining and stock-raising were possible. But our forests have been felled, our rainfall decreased, and painfully irregular in its distributions. Our soils have been denuded of their virgin mold, and are no longer capable of enduring protracted droughts, consequently our crops are growing shorter, and agriculture is no longer the pleasant and profitable profession as of yore. While this gradual decline of yield has been going on in the East, a wonderful development of agriculture is occurring in the West. Science and experience have taught that deserts with favorable climatic condition may become highly productive and valuable by the application of water through artificial means. · · · What will be the result of this immense agricultural development, with certain crops yearly?
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> I was informed this summer by a prominent United States engineer, familiar with the country, that there were yet 125,000,000 acres in this country susceptible of being irrigated, and that each 25 acres irrigated were more productive of profit than 125 acres in the East, with the uncertain seasons. He further stated that every 25 acres would then support five souls. With these facts before us, it requires no prophet's vision to see the future wealth and grandeur of this now arid region. * * *
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> And now let us discuss the subject from a home standpoint. It has been found that our maximum crops of sugar cane are produced in those years when the rainfall was well distributed throughout the season. From accurately kept meteorological records we learn that maximum crops of sugar cane are made in Louisiana after a mild and dry winter, succeeded by a spring with moderate rains, well distributed, in turn supplanted by abundant showers at close intervals during June, July, and August, winding up with decreasing rainfall in September, with the remainder of the fall clear and dry. Last year's, the largest crop on record since the war, was made with the following rainfall: January, 1 inch; February, 3.10 inches; March, 1.98 inches; April, 3.27; May, 10.71; June, 4.15; July, 7.30; August, 75; September, 4.56; October, 4.41; November, 0.87, December, 3.55, or a total of 52.65 inches, an amount nearly 8 inches below the average of five years, but well distributed for a cane crop, as will appear by aggregating into seasons as follows: Spring months, 15.96 inches; summer, 19.20; fall, 9.87; winter of this year, 7.65; winter, preceding crop, 4.53. The average for five years of the records kept at the station is nearly 59.09 inches, distributed as follows: spring, 16.58; summer, 19.06; fall, 8.19; winter, 12.46. The winter and spring rainfalls of last year were below the average, while the summer and fall were normal in quantity, but better distributed. Dry winters and moderately dry springs are conducive to subsequent large crops for two reasons: 1. The soil is put in excellent condition both as to preparation, planting, and early cultivation, and the motto a crop well planted is half made is an assertion based upon such experience and should be well remembered. 2. The above conditions, with a dry winter in this climate, are favorable to both physical and chemical amelioration of the soil. The former is apparent in its pulverization, permitting a subsequent good cultivation, and the second in the increased nitrification which takes place rapidly in dry soils during our winters. Favorable winter and spring conditions, with hot weather extending through the summer, are then needed for maximum crops.
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> The first condition in the growth of cane is drainage; that secured, the next is water, water at regular intervals, so that a maximum growth of cane may continue without interruption up to grinding. Unfortunately but few cane countries are vouchsafed these conditions by nature, and hence maximum crops of cane are rarely

made. In upper India irrigation is necessary and universally practiced. On the Rio Grande, in Texas, are sugar estates which depend almost entirely on irrigation for their supply of water. In the East Indies, Straits Settlements, and Java, so far as I am informed, the cane is grown only by moisture supplied by rain. In Singapore fine seasonable showers usually occur every fourth or fifth day, and splendid crops as a rule are raised, yet even in this favorable spot spells of dry weather do occur with great damage to the crop. Malacca, like Louisiana, has her periods of frequent showers and extensive droughts. In the West Indies long periods of dry weather are frequently reported with great injury to the crop. And yet few sugar planters anywhere appear to recognize irrigation as the great safeguard.

I may be permitted here to utter a belief that in the coming future every sugar plantation, wherever situated, will be provided with irrigation appliances and used whenever the crop is in need of water. This water can be supplied from rivers, from artesian wells, or caught and inclosed in immense reservoirs from winter rains, etc. Demonstrate the money value of irrigation and I believe human ingenuity can devise the means of supplying the water. Water is needed for the solution of the chemical ingredients in the soil, for the translocation of these substances from cell to cell in the plants, for the circulation of sap, etc. In fact irrigation is largely a chemical question, since water is the most essential ingredient entering into the growth and composition of the plants. Suppress it in part and the plant wilts and growth ceases wholly and the plant dies. With an abundance of water heavy manuring may be practiced with success, while in times of drought the smallest applications are without visible effect. Rainy years upon light soils always bring forth tolerable crops; hence the inference that irrigation on poor soils would always insure fair yields. Water is the vehicle for carrying food from the soil to the plant and produces the circulation of substances within the plant and causes the chemical processes and reactions which occur therein. It is also the very life of the plant. With abundant moisture, plants can use over and over again a given store of ash ingredients, and thus permit of an economy in these costly substances. The amount of water needed by plants is enormous; 75 per cent of our cane crop is water and 25 solids. This amount is nearly constant, and shows it must be essential for the physiological processes which occur within the plant. The contents of the cell must be kept moist. The protoplasm of each active cell must retain its glutinous semiliquid conditions in order that its functions may be properly performed. Decrease the moisture and you increase the consistency of the protoplasm, and with it, vital activity of the plant. A plant must be properly charged with moisture in order to grow freely. If not so charged, the first evidence given to us is by its wilting. By the osmotic pumping action of the roots, water is taken into the plants from the soils and rapidly evaporated through the stomata of the leaves. This evaporation is sometimes so great that a few hours of hot, dry weather would completely desiccate the plant, were not a continuous supply furnished by the soil. When the soil can not supply moisture as fast as evaporated the plant wilts. Numerous experiments have shown that this wilting occurs when the moisture of ordinary soils at 80° F. is reduced 10 or 15 per cent. This wilting does not betray the first suffering of the plant, but rather the beginning of decadence. Experiments have also shown that for crops like sugar cane, there is evaporated during growth, at least 300 pounds of water for every pound of dry matter contained in the cane. Our cane and tops contain about 25 per cent of water and 25 per cent of solid matter. On a crop of 40 tons of cane per acre there would be fully 12 tons of leaves and tops, making 52 tops of product. Of this 52 tons there would be 13 tons of dry matter. If each ton of dry matter utilized 300 tons of water, the crop during growth would have consumed 3,600 tons of water. One inch rainfall gives 27,154 United States gallons, or 113 tons per acre.

Our annual rainfall is about 60 inches, or about 6,780 tons per acre, nearly twice as much as would be needed to grow this crop provided it fell during growing season, and that none of it flowed off the surface through the quarter drains. But what are the facts? A large quantity of what falls goes off to the swamps, certainly 20 per cent, and during the spring and summer months, the season of growth, the average rainfall is about 35 inches, or a little over 3,900 tons, enough, if it were distributed, and no loss through quarter drains, to supply the above crop. But our rains are not well distributed, nor do they fall in such gentle showers as to permit total absorption by the soil. Hence the water to secure this large crop must be obtained from the winter supply in the soil and irrigation. * * * Our experiments this year show that the water delivered through a 6-inch pipe would easily irrigate 20 to 25 acres in twenty-four hours. Another benefit of irrigation with Mississippi water is fixation of matter held in solution and suspension, and its subsequent utilization by the plant.

This fact, first noticed by the French chemist, Maliguti, has been since fully established, and is expressed by practical men when they speak of water running off their plats "as used up." The double silicates and humus of the soil have the power of withdrawing from the spring and river water, potash, ammonia, magnesia, and phosphoric acid and to a less extent of soda and lime. The excess of oxygen in the air of river waters also quickly unites with the oxidizable matters and is consumed. According to Humphrey and Abbott, the sedimentary matter carried by the Mississippi River is one part in weight to every 1,500 pounds water, or 1.⅓ pounds per ton. This matter is almost entirely deposited on the soil during irrigation. Besides this sediment, a small amount of valuable soil are held in solution, some of which are absorbed by the soil, and in the large amount of water used for irrigation these manurial additions have no small influence on the growing crop.

Do we need irrigation on our cane crops, and if so how can we best supply it? This is the chief question to-night. Our climatic conditions do not give us equable seasons. The first is easily answered in the affirmative. Droughts and excessive rainfall follow each other without regard to the season. Seedtime, cultivation time, growing time, and harvest are all subject to these variable conditions, frequently causing immense differences in the profit account of the farmers. How much seed has been lost in dry rot, when a slight irrigation of the soil would have prevented it! How much seed has been planted and covered in dry, cloddy soils with little or no prospects of full germination because the planters could not wait for a rain! How often have we rolled with the plow and cultivator the obdurate clods to and from the young and tender cane of spring in our honest but fruitless efforts to pulverize them, when a mere saturation of them with river water would have caused their disintegration! If we reduce our crops to a money value, and estimate that of last year at 100, then our average annual losses from drought are fully 20 to 25 per per cent. To grow maximum crops our plants must be pushed from the germ to the sugarhouse. This can only be accomplished by a full supply of plant food, good cultivation, abundant sunshine, and sufficient moisture. The amount of moisture needed during summer by the cane crop is enormous, and any deficiency of at least 1 inch rainfall per week during the growing season, is believed to be fatal to maximum growth. Less than this amount of water falling, the moisture should be supplied by irrigation. From a close study of the books kept at the sugar experiment station, it is believed that irrigation could have been successfully practiced at least fourteen times in the five years ending January 1, 1891, and four times this year have we irrigated with success, making eighteen times in six years, an average of three times per year. Having established the benefits of irrigation, the question is how and where shall we obtain our water? To one who has recently witnessed the enormous labor, time and capital necessary to secure water upon our lands far removed from rivers, the question affords an easy and ready reply, viz: From the Great Father of Waters and its outlying bayous flowing past our doors nearly every sugar planter can draw all the water needed. A boiler and pump or an elevator of some kind is needed to lift the water over the levee. If siphons be used the former would only be required while the river would be below its banks. Some may say that we can not irrigate a thousand acres of cane. I may reply that they have already accomplished far more difficult and less profitable enterprises.

The writer has seen successfully irrigated fields of far greater inequality of surface than most of the cane fields of Louisiana. Lay off carefully on each place the line or lines of greatest elevation, running from the levee to the rear, and constructing ditches along these lines for the conduct of water through the plantation, and into these ditches pump the water. From these ditches have quarter drains running into each plat, and use these as laterals and distributaries, filling plat after plat, using wooden troughs to cross the drainage ditches. I verily believe that the plan can be easily and cheaply executed on every plantation, and the saving in one crop will pay for the entire outfit.

We have already published an account of our irrigation experiments at Audubon Park. They were begun too late, and yet the results are astonishing. Our drought began on March 16, and irrigation was not begun until May 4. In the meanwhile our canes had suffered, and the effect of this drought is apparent I believe to-day in the decreased diameter of the canes over last year. The height is fully as great and the number to the running foot greater than last year; but nowhere among either home or foreign canes have we the size of the stalk, which defect we attribute to early drought stunting the size of the cane. Irrigation was subsequently applied as follows: May 18 and 19, June 3 and 4, July 1 (on one plat only a shower making further irrigation unnecessary), and September 7 only on spring plants. There are five tile-drained plats on the station. All the tiles are connected with the common main. In the beginning of our experiments it was determined to leave two of these plats unirrigated, and our plans were so adopted. In irrigating the three plats it was found that the tiles were discharging the water nearly as fast as we were pumping it in, and it was necessary to hold it on the plat to make it reach several spots that were higher than the rest. The main discharge was, therefore, closed, and in a few hours all five of the plats were wet—three from surface irrigation and two from the raising of the water through the tiles or subirrigation. This first experiment was repeated, each subsequent irrigation with similar results.

During August another drought prevailed. I was absent at the time, but daily expected, and on my coming everything was ready for irrigation, so, on September 7, when the canes were polarizing 8 to 10 per cent sucrose, we gave two plats another irrigation and only stopped from irrigating the entire crop by excellent showers which have prevailed ever since. Now, for the results—cane, corn, cotton, and cow pease have been irrigated during the year. Six acres of corn were forced by irrigation into early roasting ears and sold to the Italians. The amount realized from this source was nearly $500. Enough was left undisturbed to show that the yield was over 100 bushels per acre, while another patch irrigated gave a yield of about 25 bushels per acre. The other crops have not been gathered. They are subject to inspection by any one interested in irrigation. The cane crop, it is believed, will be as large as the very large one harvested last year, and is in strange contrast with a piece of spring plant, which never received any irrigation whatever.

In closing, permit me to say, that from a close study of cane-growing for six years, I am convinced that water as an element enters as the predominant factor into the problem of successful sugar-planting in this State. How to get rid of an excess is the great question of drainage, already studied and developed. How to supply the deficiency is the present and future agricultural problem, and I verily believe that this intelligent body will furnish as satisfactory a solution of this momentous question as it has done in the past with the many serious issues which have engaged its attention.

In the discussion that followed Dr. Stubbs's paper, the doctor said that the necessary ditches could be made for from $2 to $5 per acre. The cross laterals ought to be small. He added:

We found in our experiments at Audubon Park that, starting the water about half an acre from the fence, and running down parallel with the circular road, a stream that I should say was about 1 foot wide and about 6 inches deep, we irrigate five plats, running three or four streams in six to twelve hours. Now, as to the streams, the number, of course, depends entirely on the size of fields to be irrigated.

Ours is a common 6-inch pipe, having a drainage trough. That 6-inch pipe can easily irrigate 20 to 25 acres per day From the time we commenced, say we would get to work about 9 a. m. and close somewhere between 9 and 12 p. m., we would irrigate from 12 to 25 acres in a day. Ours is a force pump, and we could irrigate from 20 to 25 acres in one day. The main pipe is a 6-inch one, as is also that leading off from the discharge. The latter flows into the trough that irrigates the field. We use an old pump, and if it had new pistons, it could drive with more force and lift more water. I do not think there will be any trouble in getting water over our lands if there is another drought of seven or eight weeks. I am satisfied that the results of the park would have been far more satisfactory had we commenced irrigating sooner. We commenced May 4, and I think had we started about the 20th or 25th of March our cane would have been fully 10 per cent better. Our canes should be wet at least once a week from the time they germinate until ready for the sugar house. Where the soil was subirrigated the soil was not disturbed at all. I could hardly tell that any water had been on it except a little flood that I saw rising; while on the other plats that were surface irrigated it left a hard surface on the top; so I prefer subirrigation. Now, we permit the water on the surface first to filter through the soil to the pipes, then rise back through the tiles onto the soil. * * * I will state if the water was kept in the tiles perfectly still some of that deposit would be deposited therein; how far it would be washed out by subsequent rains I can not answer. I never had any experience. I hardly think it would. Of course, we send into the diffusion battery water perfectly muddy and dirty; when it comes out it is as clear as it can possibly be. It is filtered through the chips and is perfectly clear.

Mr. Soniat also said during the discussion:

I have tried to irrigate cane as you state on the rice plan, but the trouble was it stayed too long on the land. Dr. Stubbs is better favored than I was. His land is new, being land that has laid a good many years idle, consequently porous, and he may have risked putting water on the land two days without any injury whatever; but I have tried it on old lands and always found injury done to the cane thereby. If water remained in certain places I found in a few days thereafter the cane would turn yellow. I have always found that if water remained too long on young cane in the springtime the cane would be injured. I think by leaving the water start at one end to flow down the furrows, and not to permit it to remain longer than a day or two no injury will be done. On the contrary the cane will be much benefited, provided the day thereafter, as soon as the land becomes dry, the crust is broken, which permits the air to penetrate the soil. I found that in this way a great deal of good was accomplished. I tried it only one year on sugar cane, but have used it mainly on truck farming. We take water cans and sprinkle the plants, but you could never do that with cane; truck farming is entirely different. The hills are far apart. One man can water an acre a day and it is very cheap. But watering sugar cane with watering pots is a very different thing. I think the only practicable way is, as Prof. Stubbs has done, to flood; but as soon as possible thereafter the soil should be drained, and under no circumstances allow the water to remain on the land any more than one day, and immediately thereafter plow the land—the same as we are compelled to do after a rain flood.

If a planter leaves his crop after a rain flood from three to six days, as soon as it dries the soil will crack and the sun will penetrate the roots, and in this way much injury is done. If all the cracks are stopped up, of course the sun will not go through the ground. The roots then become exposed to the sun, and in this way the roots are struck, destroying their vitality, and the leaves then turn yellow. I think there is a great deal more injury done in this way by the sun than by floods. Prof. Stubbs and myself have been studying this for years, and I think anyone can follow his footsteps with safety.

"Sugar Cane Irrigation" is the title of a paper read by Mr. Adolph Thiel before the meeting of the Louisiana Sugar Planters' Association, October 8, 1891, extracts from which are here given:

* * * As the success of irrigating sugar lands has been demonstrated beyond a doubt, I think it pertinent to consider the most advantageous mode of irrigation, in conjunction with the subject for discussion. It will be remembered, perhaps, that I have advocated for more than two years the use of drain tile for irrigation purposes, basing my theory upon the fact that the water, if forced into the tile, would distribute itself through the soil in the same pores and channels that it finds its way to the tile in wet weather. Dr. Stubbs's experiment in irrigating two tile-drained plats proved the correctness of my theory beyond a doubt. Although an account of the experiment has appeared, for a better understanding I will repeat the report in brief, which is in substance that plats 3, 4, 5, 6, and 7 had been tile-drained in early spring. In order to determine the difference of results on tile-drained land irrigated and tile-drained land not irrigated, plats 4 and 6 were not irrigated. But as the water would not run beyond the first line of tile on each plat it was found upon investigation that the water escaped through the outlet tile, which was then stopped up to prevent any more waste of water, with the result, however, that the water was distributed throughout the tile-drained plats (they being connected with each other through the main tile), and all of the tile-drained land was equally irrigated and benefited, as I could see no difference in the looks of the cane when I saw it.

It is claimed by opponents of subirrigation that in this experiment the water found its way to the surface simply because the dirt over the tile had not become settled or puddled at the time, and that the water rose to the surface in that place only. I am prepared to meet that assertion with a statement from Dr. Stubbs to the effect that moisture appeared on the surface of plat 7, which is from 6 to 18 inches higher than plat 6, the highest place where water was applied. The appearance of moisture on the surface of plat 7 was due solely to capillary action.

The entire practicability of subirrigation being demonstrated, it remains only to point the advantages of such a system over another. * * * By surface irrigation considerable time elapses before the soil can be stirred after the water has been applied. In California and other places where crops are raised by irrigation exclusively, the ground is stirred with the plow or cultivator as soon as possible, and no doubt the rule should hold good in irrigation of sugar cane as long as it is not laid by or not tall enough to shade the ground sufficiently to prevent the cracking or baking of surface soil. But as even the Mississippi bottom lands are rarely smooth enough for the equal distribution of water over the surface, with surface irrigation more water will accumulate in some places, delay the stirring of the ground, and cause loss of moisture by evaporation. On the other hand, with subirrigation, stirring of the soil may be carried on simultaneously, thereby preventing any waste of moisture.

In order to distribute the water equally by surface irrigation numerous dams and channels are necessary, demanding constant attendance. These dams and channels can only be temporary, as they would interfere with the surface drainage in case of wet weather. By surface drainage the channels are permanently established, as a uniform continuous grade is essential to the success of a tile drain. By the addition of the few valves, any system of underdrainage can be made to serve the double purpose of drainage and irrigation.

On the question of "Artesian wells for irrigation," Mr. R. S. Rickey, manager of a "hydraulic wells" company at New Orleans, writes to the Planter of October 17, as follows:

In experimenting with irrigation during the spring and early summer drought, Mr. Benjamin Bourgeois, manager of Mr. Leon Godchaux's Elmo Hall plantation, irrigated a piece of black stiff cane land which seemed to be dying, and it is now as good as any plant cane he has. Drauzan Himel, of Assumption Parish, says that by irrigation during the same period they saved one-half of their crop and made the only good corn crop.

In speaking of wells and their capacity, we put down two 6-inch wells on Elmo Hall for Mr. Godchaux this year, and measured their capacity by pumping the water into large tanks. In this way we ascertained that the two wells gave 765,000 gallons of water in twenty-four hours, with Bayou Lafourche at its lowest stage. A 6-inch well just completed on Messrs. Whitehead & Kent's Abby plantation, Lafourche, gave at the rate of 465,000 gallons of water in twenty-four hours, while a 4-inch artesian well at the Calcasieu Sugar Company gave at the rate of 500,000 gallons in twenty-four hours. We are now negotiating to put down an artesian well for the town of Lake Charles.

The same parties have put down, according to Mr. Rickey, in all 102 "hydraulic" wells in the sugar district, 45 of them being made during the past year.

A "dahl" is a flume built in the river levee for the conveyance of water to the rice fields. Their situation, unless properly gained, tends to weaken the levees. Hence the legislature has provided for rigid requirements. During the year 1890, however, such a flume weakened the Ames levee near New Orleans, and caused a serious crevasse. It is asserted that the old system of construction was more efficient than the new. It is thus described by a New Orleans writer, Mr. W. W. Pugh:

The old fashioned "dahl" is made of sound 3-inch cypress plank of one length. This is supported by three brick walls, built so as to extend some distance above the top of the woodwork, in order to interfere with the work of crawfish and muskrats, which would otherwise follow along the line of woodwork and give rise to leaks, and finally to the blowing out of the whole woodwork of the "dahl" and leave a large opening in the levee through which the water would rush with a mighty force. In addition to the walls, but as a support to the dahl, good lime and plenty of it is used to form a strong front to the brick between the brick walls, which in a few days becomes hard, and when the dahl is taken up for renewal, or any other cause, requires to be removed with a pickax.

The State law demands that the dahl should be made of iron instead of good cypress lumber; it does not require the support of brick walls or the surrounding of the iron pipes by strong mortar or grout. There is no obstacle then to crawfish and muskrats, and leaks at the joints of the pipes or along it will necessarily in a short time end in its being blown out. Flumes constructed of good 3-inch red cypress plank will hold good for ten years or more. They are built of one length, have no joints to leak, and if properly constructed and laid down are just as reliable as the inch pipes as long as they last. These flumes should be replaced every five years. Iron pipes soon become honeycombed with rust.

The season of 1891 was marked in Louisiana by long drouth, beginning in some portions of the State as early as the latter part of March. This condition created a great interest in irrigation. Mr. S. Mills, of Oakley Plant, Albemarle post office, wrote the Planter under date of May 26 in relation to his experience as follows:

After five weeks of irrigation on a place whose peculiar topography enables me to irrigate naturally with swamp water over three-quarters of it, I still find myself very much in the dark, and with far less success than I at first anticipated. I see before me fall-cane, and some succession cane, with water in ditches up to the water drains for the past four weeks, parching up, and not a few stalks dying, the ditch-bank rows, right along the water's edge, suffering even more than the interior rows. The middles show considerable moisture to the plow, and in some places, the water having slightly entered the water drains, a profuse growth of "milkweed" shows along the edges, but the cane still refuses to be comforted, and like the paradoxical shipwreck, still cries for water. I have also in some portions of the field, pursued another course of irrigation. I dammed up my ditches at the first water drain of the upper end of the cuts to be watered, closed the outlets of the water drains (excepting the first one alluded to), leaving the ditches open through the cuts, and allowed the water to rise sufficiently to overflow the first water drain and follow the dip of the land.

By the first system the water rises, or is supposed to rise by capillary attraction up to the cane; by the second system it percolates through the soil downward just as a rainfall would and eventally reaches the ditches. Under the first system I can see no perceptible benefit to the cane; under the latter considerable. I take it that the second system is as near the mechanical action of rain as we can obtain it on any extended scale. I am not set or at all settled in the matter, but if the latter view should prove generally correct, a small pumping outfit on wheels, capable of being easily conveyed and turned about on the turn rows, with a capacity of irrigating 20 or 25 acres a day, might be got up for about $1,500, and would be a valuable adjunct for other purposes on a plantation.

By taking cut after cut, closing the outlets of the water drains and pumping water on the highest point from running water in the ditches, guided only by such small locks or dams as might be needed to have water accessible to the pump, I think such a course and outlay this season would have reclaimed an immense amount of plant cane and many times over repaid the investment.

Siphons in connection with pumps are coming into use in Louisiana for the conveyance of water over levees, when needed for irrigating the can and rice fields. It is considered by many a mode of conveyance cheaper than a flume, which latter method is more largely used. Mr. Sherland, a planter, says that—

In order to insure the full performance of a siphon it should be made of iron heavy enough to be calked, the same as a steam boiler. This idea of making a siphon of thin tank iron and depending upon the rivets and lead to insure a tight job is a fallacy. While new, it may work a short time, but the iron being in the sun will expand and contract in the different temperatures that it is subject to, will soon loosen at the joints, and a planter will condemn a siphon and tap the levee to obtain his supply of water, and by so doing he will soon have a supply of water, and his plantation can only be found by the sailor's lead.

Again, there should be in the lower end of the siphon some means of holding the water until the pump has made a perfect vacuum. Then, when the lower end of the long leg is opened, there will be a solid volume of water flowing until air accumulates in sufficient quantities to cause a cessation of the flow.

All water that is exposed to the atmosphere contains a certain amount of air, and that air will seek the top of the water whenever the conditions are favorable. Hence there is a tendency to lodge in the highest points of the siphon until sufficient has accumulated to cause the water to cease to flow. Siphons should not be condemned until all laws governing the flow of liquids have been complied with. With regard to the presence of air in the siphon preventing its proper working, Mr. Soniat, president of the Audubon Association, says, in a published communication, that the remedy for the hindering accumulation is to have an "air vessel on top of the siphon. The horizontal portion of the siphon lying on the top of the levee should be slightly arched; then, by placing the pump at the top of the air vessel, it will fill the whole siphon and air-vessel with water. A glass water gauge on the side of the air vessel will show when it is full and will insure a steady flow of the full capacity of the siphon. This is an experiment." He adds, that "when once understood, a siphon is no more trouble than a flume; is cheaper; requires no cutting of the levee, and, if required, can be moved from one place to another with very little work. The main point of having a properly constructed siphon is to place it so that both ends will be covered with water, and to have in front a small reservoir to allow time to close the siphon in case the pump stops."

The irrigation experiments of the Sugar Experimental Station (Audubon Park), Louisiana, during the planting season of 1891, are of importance to cane planters. In describing these experiments, it is said:

Our climatic conditions do not vouchsafe to us equable seasons; droughts and excessive rainfalls follow each other without regard to the time of the year, seed time, growing time, and harvest, and all subject to these variable conditions, frequently causing large differences in the profit accounts of the farmers. Tile drains are believed to be a remedy to heavy rainfalls, and to a large degree will mitigate the severities of a drought. But, however well laid, they can not supply the necessary water for growing crops in a protracted drought.

It seems essential for the production of a maximum crop of cane in this climate that the plant should be pushed into growth as early as possible in the spring, and maintained in a healthy, vigorous, growing condition until fall. This can be done only with showers at short intervals, extending through the spring and summer months. Unfortunately, this rarely occurs. * * * Experience has demonstrated that whenever the rainfall for a month during the growing season is less than

2½ inches, the plant fails to accomplish its maximum growth, and may with profit be assisted with irrigation.

* * * * * * *

It is believed that the Father of Waters, so often a terror to our planters, could sometimes be used with considerable profit in supplying our crops in the growing season with water, when the rainfall is less than 2½ inches per month. To find out how often this accessory to our wealth could have been profitably used in the last five years, a special study of the carefully kept meteorological record of the Sugar Experiment Station has been made. For five years the average annual rainfall has been 61 inches, distributed as follows:

Average for—	Inches.	Average for—	Inches.
January	4.42	July	6.21
February	6.52	August	8.03
March	4.51	September	4.34
April	3.39	October	3.06
May	6.68	November	1.81
June	8.42	December	3.59

A fuller examination of the record shows that 14 times in five years has the monthly rainfall been less than 2½ inches. Of these, 6 have occurred in the growing season; 3 in April, 2 in March, and 1 in May. Then, at least 6 times in five years could an additional supply of water have been provided to our crops with profit. Yea, more; it is now confidently asserted that 25 acres under ditches, with intelligent artificial irrigation, will produce more than double that area naturally watered.

Irrigation, then, should have been used advantageously many times in the last five years, even when the monthly rainfall was an average one. The entire sugar belt of Louisiana has been visited this spring by an unusually protracted drought, causing great injury to late planted cane and retarding the growth of both fall plant and stubble. At the Sugar Experimental Station there fell, on March 16, 1.44 inches of rain. From that date to May 4, only 1.48 inches fell, distributed in six showers, at intervals of nearly a week. It was therefore very dry and crops of every kind began to show the want of moisture.

A plan of irrigation was devised and steps taken to execute it. On Monday, May 4, the pump was started and 3 acres of plant cane was saturated with water. The operation began at midday and closed soon after dark, letting the water remain on the cane all night. The work was well done, in fact successful in every respect, but the fruits of the work were destroyed, for while the land was thus under water at 8 p. m. there came a terrific storm, a perfect waterspout, accompanied with hail, lightning, and thunder. There fell in about one hour 1.6 inches of rain.

This rain, while a perfect blessing to this community, for it was confined to a small area, was destructive to the experiment. However, early the next morning the quarter drains were opened and the water let off in the ditches, and up to date there are no visible signs of injury to the cane irrigated. The method of irrigating was a simple one. The plats on this station are a half acre wide and extend in length entirely across the field. Between each plat is a headland or drive 15 feet wide; a quarter drain separates each plat from the headland. There are no quarter drains in the interior of the plats. The ditches run at right angles to the plats. When these grounds were used for the exposition a complete water works was established for the entire park.

Two underground pipes of theirs cross our station at right angles to our plats, one 16 inches in diameter the other 6. Where these pipes cross our headlands they were tapped, and proper sized short pipes with plugs inserted. These pipes were arranged so as to discharge into quarter drains.

The water flowed from the quarter drains down the middles of the rows, and when they were full and the moisture appeared on the top of the rows, the quarter drains were dammed and the water directed to another plat. Ditches were crossed by wooden troughs large enough to convey the flow of the water. By this experiment it was found that every plat on this station (nearly 50 acres) could be successfully and easily irrigated.*

The first experiment was interrupted by a light rainfall. The dry weather, however, still continuing it was decided to try irrigation once more. On 10 acres of land without underdrainage, water was turned on for eighteen hours; 7 acres were in corn and 3 in fall cane. The temperature of the water was found to be from 70° to 71° F. Five acres tile-drained and planted in stubble cane were then irrigated. The first irrigation was that by flooding. The second would be that of sub-irrigation. Some difficulties were met in the lay out of the several plats, of which there were five, being tiles 3 inches in diameter and placed 40 feet apart, by each string running into a common main 5 inches in diameter, discharging at the lower end of plat 3. It was determined to irrigate plats 3, 4, and 6, and leave 5 and 7 without water. Plats 6 and 7, the last tile-drained and used in ditching, were not thoroughly compacted. Hence, one of the plats consumed water too rapidly, preventing equal distribution upon the other plat. After partially closing the 5 inch discharge pipe, the irrigation was continued more rapidly. All the underlaid plats by tiles were found to have been subirrigated. Three of the plats were served by surface irrigation or flooding. The report in the Planter states the result as follows:

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* Louisiana Sugar Planter, May 16, 1891.

> The tiles are 4 feet deep, and the water had been therefore forced up through a layer of earth of this thickness. Thus both irrigation and subirrigation had been demonstrated. After eighteen hours the pump was stopped, the plats left full of water and the obstruction in front of the main pipe removed, and all retired to await the results of the morning. At 6 o'clock it was found that nearly all the water left on the plats had been removed during the night by the tiles, and it was estimated that a few hours more would have removed the last visible water, thus showing the value of the tiles in removing excessive rainfalls. Patches of sorghum, cowpeas, and Peruvian cotton occupying a part of tile-drained area were also surface irrigated. It may be mentioned incidentally that about 2 acres of corn first irrigated was unintentionally flooded again next day, making nearly forty-eight hours of inundation. The results of these experiments are plainly visible. The irrigated corn is in marked contrast with that unirrigated, both in size and general appearance. The cane is growing rapidly from the effects of its recent baths, while the sorghum, cotton, and even cowpeas are giving striking evidences of their superiority over those not irrigated. Not a single yellow stalk or "sere and yellow leaf" is anywhere visible from the effects of irrigation, while a dark green coloring, everywhere to be seen, gives striking evidence of its value.*

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* New Orleans Planter, May 30, 1891.

FLORIDA.

The conditions of cultivation in the Peninsula State tend rapidly to impress the need of water conservation and distribution upon the intelligent planters, orchardists, and truck-farmers thereof. They are engaged in raising crops of large commercial value and can not afford to depend upon the uncertainties of nature. The soil is largely unretentive of water, and the temperature, as well as rainfall, at the growing season requires careful attention, with the husbanding of resources adapted to the deficiency and wants that arise. The rainfall being uncertain while the heat is great, irrigation becomes an essential part of the economy of farm and orchard. In all directions then there is an active effort to supply the want of precipitation and the loss caused by evaporation. It is conceded on all sides that the lightest and most barren of Florida soils can, with plenty of water and a modicum of fertilization, be made very productive. The Office of Irrigation Inquiry has received the following accounts of artesian wells and of irrigation plants in use for the utilization of those and other supplies: The most successful and as it probably is also the most thoroughly practical experiment yet made in irrigation by artesian water is that of Thomas H. H. Hastings, of Hastings (Merrifield post-office), in St. Johns County. Mr. Hastings is a Northern man, who, on "flat woods" land, cultivates early vegetables on an extensive scale. The results of his efforts, both in irrigation and maintaining the temperature in his "cuke" or cucumber and other forcing houses, have attracted wide attention. In answer to the inquiries of the Irrigation Office Mr. Hastings furnishes the following particulars:

The average is a flat pine wood land, with a clay subsoil from 12 inches to 2 feet below a rich top soil which can be ditched with a subsoil plow, said ditches carrying and holding water as well as piping. My beds are all laid off 20 feet wide, ditched each side; the water percolating on top of the clay, moistening the entire ground to the top. I can completely flood my beds, washing off and drowning cutworms and caterpillars.

The cost of clearing and preparing, drainage, and ditches, is $55 per acre; palmetto scrub costs more; fencing is extra.

"My well is 239 feet deep, with a four-inch bore. Total cost was about $450. Flow of water sufficient to irrigate from eighty to one hundred acres. Force, from about three to five horse power. Natural flow upwards, about thirty feet. Have fine waterworks system from a one-inch pipe attachment to well in my house; bath room in second story of my house. Can attach turbine water wheel.

As to the system of planting and water utilization, Mr. Hastings says:

Did not plow the whole ground; had no time. Dug trenches, put in compost, hoed the grass between trenches, which are 4 feet apart, built tomato frames out of rough boards, 150 to 200 feet long, 5 feet high to the north, sloping 22 feet to the south, where frames are 2 feet high. Use prepared heavy grade waterproof cloth curtains, which I roll down over the plants on cold frosty nights. Found the curtains perfect protectors from frost. Use same curtains in summer to protect plants from heat of sun. The sun always shines in Florida unless it rains, which is very seldom, except in the rainy season—the months of June, July, and August. I dig ditches outside and around the frames, filling them with water to irrigate the plants in the trenches, thence turn the water loose, and the same ditches answer for drainage and for trenches.

In his "cuke" house (which is 165 feet long and 22 wide, costing about $1,400) Mr. Hastings uses his well water for heating. He says that in this house the—

> Two side benches are 3 feet wide, my two middle benches are 5 feet wide each, two rows to a bench. Moisture and heat are furnished by water at a temperature of 79° from my well by permitting this water to run all frosty nights underneath the benches the entire length of the house.

Messrs. Hastings and U. J. White (whose statement follows Mr. Hastings') own between them over 12,000 acres. During the past season they harvested 400 acres in rice, averaging from 75 to 100 bushels per acre.

Mr. Hastings writes:

> This was our first year's planting, on new land, only broken about eight months past. This is upland rice. Requires no more water than used for truck gardens. We expect to get from $1.10 to $1.25 per bushel for hulled rice. Will lose from 30 to 40 per cent in hulling, according to quality of rice. In August, 1890, I began my improvements, and did my first plowing. Mr. White began a year and a half earlier. The rice straw, when properly cured, furnishes excellent ensilage and feed for all kinds of stock, which eat it clean. * * * We will buy no more hay. Am planting now Irish potatoes, early turnips, and preparing ground for planting Bermuda onions; also planting celery seed in hot beds.

Mr. Hastings, in replying to office inquiry, states that in his neighborhood there are seven artesian wells, and within a radius of 7 miles some twenty, of which thirteen are used only for orange orchard irrigation. For fruit a sandy soil is used. In drilling for water, the first flow was obtained at 190 feet, the second at 239. The pressure is 10 pounds to the square inch, and the water rises above the surface about 30 feet. Temperature ranges from 74 to 79° F. No change seen in the flow, and the water is slightly sulphurized, but very clear. For irrigating about 100 acres from 3 to 5 horse-power is used.

A committee report read before State Horticultural Society, in May, 1891, describes their visit to the irrigated farms of Messrs. Hastings and White. Of the first named the committee says that Hasting's was not in existence in August, 1890. They state:

> We soon discovered the great factor of it all in a 4-inch artesian well. This well is but 250 feet deep, yet the volume that rises is enormous and with such force that no pumps are needed to elevate the water to any part of the house or barn. The temperature of the water remains at about the same—79 degrees—the year around, which is a great advantage in gardening during the winter season. Close to the well the "cuke" house is built, being 165 by 22 feet, containing four beds, which run the whole length. The house is covered with glass and built similar to green houses North, only that it does not have to be so strongly protected against cold and has no steam-heating apparatus. The heating of this house during the cold spells that occur during December, January, and February is quite novel as well as original, and we venture the assertion that nowhere in the world is it done the same way. When the "signs" indicate that a cold night is approaching the well is opened and the stream of water is conducted to the cuke house, where it flows under the beds in a stream from 3 to 6 inches deep. This current of water keeps the temperature at an average of 60 degrees on cold nights, frequently making a difference of from 20 to 30 degrees between inside and outside.

After describing the tomato frames and the prairie garden the report goes on to say that—

> All this was done with the aid of irrigation, the artesian wells furnishing the supply, although nearly half a mile off. Irrigation is done by means of ditches dug one side of the field. When a certain piece of land is needing water the trenches on both sides of it are dammed up and the water is allowed to fill the intervening trenches until level with the surface, and is then dammed in and left to percolate through the soil, which it will do in a very short time.

Of the rice culture it is said:

> After vegetables are all harvested and the land plowed it is planted to rice and the

water turned on. In a great deal shorter time than one would think the ground is thoroughly saturated and the rice sprouts, and a good stand is the result. Thus the land can be kept in continued use the year round. All that can be done on this land remains yet to be proven, for the work that has been done is only a beginning, for it would be impossible for any one or two men to develop it in so short a time.

U. J. White, of Merrifield, now irrigates and cultivates 350 acres by means of four artesian wells, each yielding 300 gallons per minute, or in all 1,728,000 gallons each twenty-four hours. The water is heavily charged with sulphur. Drilling began in October, 1889, and was not completed until February, 1891, when the last well bore was made. The water rises above the surface a distance of 30 feet; the temperature is 74 degrees; there is no perceptible diminution of flow; the casing is 4 inches clear, through hard rock, to a depth in different wells of from 150 to 250 feet. The cost was from $200 to $400.

The drainage ditches on the farm are used to carry the well water for irrigation, flood-gates being put in at needed points. Main ditches are filled from the wells, and the water then backs into the laterals and furrows. The land is very level, with a clay subsoil, averaging 18 inches in depth, and materially aids the retention of the water about plant roots. The drainage system prevents undue filling of the soil. The rice fields are flooded by the throwing up of dikes around and then flooding the basin thus formed by water from the wells. The cost of preparing land is estimated at $20 per acre, and the cost of irrigation plant at $5 per acre. The cost of the four wells did not exceed this; certainly a very cheap system. Mr. White is enthusiastic in support of his own methods and results. There is in all 500 acres under cultivation by irrigation in his neighborhood. Fruits, semitropical and temperate, vegetables of all kinds, peas, beets, etc., and rice are the principal crops. The average returns under irrigation, except fruit which is large, is reported at from $50 to $60 per acre.

The visiting committee of the State Horticultural Society, whose report we find in the Florida Agriculturist, published at Deland, gives the following in relation to Mr. White's work:

> We found Mr. White busy shipping cabbages from a 40-acre tract, and trying to figure out how much he would make at $17 net per car load, a large prairie of 400 acres, nearly all of which is covered with a crop of rice just coming up. This land three months ago was in its virgin state. Right through the center of this tract a canal is cut which is about 3 miles long. Into this canal the water from three artesian wells is turned and from here it is carried to all parts of the rice field. One can see a rice bed 1¼ miles in length with water flowing at every 40 feet. Last year, on some trial beds of rice, Mr. White gathered nearly 100 bushels to the acre, and the product was pronounced as fine as any from Louisiana or South Carolina. Some South Carolina planters have become very much interested in it.

C. A. Bacon, of Ormond, Volusia County, writes at some length, saying:

> In the year 1883 I had a 3-inch artesian well put down. The surface is 10 feet above high tide in the river, which, according to U. S. Coast Survey, is 13 inches above tide in the ocean. (We are located at the head of the Halifax River, 5 miles north of Ormond.) The well will cease to flow about 2 feet above the surface. At the surface it flows from 40 to 60 gallons per minute at high tide in the ocean, and 30 gallons at low tide. In drilling the first 30 feet we passed through shell 6 feet, then coquena and quicksand, the balance blue clay to 90 feet, where we struck the bed lime rock and obtained a small flow on top of the rock. The casing ceases at the rock. From the 90 feet rock to the 163 feet depth, where we finally stopped, we passed through at least fifteen strata of coraline rock, varying in thickness from 1 to 8 feet. Between the strata there were seams; sometimes the drill would drop 2 feet. We had an increase of flow at 108 feet, and the best flow was at 128 feet; no increase after that. The water seems to be unlike any other in the State; visitors say it is identical in taste to the "Blue Lick" water in Kentucky. The Department of Agriculture gave a qualitative analysis, viz.: Composed of chlorides and sulphates of soda, magnesia, potash, and lime, 280 grains solids to the gallon.

The first six months after the well was put down, I ran it in trenches around orange trees, guavas, etc. Since then it has run in a trench some 300 feet through my grove, within 8 feet of a row of orange trees, the next row being 12, the next 32 feet, and I can not see a particle of difference in the trees, or rather in their growth, either within 8 feet or 100 feet of the running water. I had about concluded to let the Lord do the irrigating.

This summer, however, I have built a cement wheel-pit, the bottom on a level with high (common) tide in the river; I have put in a 10-foot water-wheel; face plate on each end of shaft; two No. 3 Douglas force and suction double acting pumps, stroke 5½ inches. The water from the artesian well 80 feet distance turns the wheel from three to four turns per minute, according to the tide in the ocean. One pump takes the water that (or a portion of it) carries the wheel in a 1¼ inch pipe, to a 5,000 gallon tank, located 500 feet from the wheel. The top of the tank is 50 feet above the bottom of the wheel-pit. The other pump, lifts fresh water from a driven well through the bottom of the wheel-pit in 1-inch pipe to barn, house, etc., and then joins the 1¼-inch pipe, where the surplus goes into tank. The 1¼ pipe screws into the bottom of tank, so that my lateral pipes (1 inch) connect with it, to save piping back from tank. My wheel and pipes will now fill the tank in about two days. I have 1,400 feet of pipes laid. My object is to irrigate the home acre or rather the home 3 acres, flowers, and small fruits, etc. I can attach at the farthest hydrant 100 feet of ¾-inch hose and throw the water 35 feet from end to nozzle; can attach a whirligig to hose and irrigate a circle 50 feet in diameter. I am well pleased so far; but, alas, man is never satisfied. I have a sprocket wheel on wheel shaft, am negotiating for a 4-inch well, and mean to make the old wheel hum, turn my grindstone, and cut my feed. On my wheel I am using about 40 gallons per minute, with a fall of 6 feet. We are convinced that on our droughty soil a little water is worse than none. When we know that an inch of water on an acre weighs a hundred tons, we begin to appreciate the irrigation system. I am making basins around my trees and plants, will put in fertilizer mulch, and keep wet. I believe there are spots on my place that have not been soaked for three years. My house is 2,000 feet from the ocean, near bank of Halifax River.

The Rev. Lyman Phelps, of Sanford, in Orange County, writes that—

In the section about Sanford, in Orange County, there are many artesian wells, but none used for irrigation. Some fifteen months ago I began work on a 3-inch well to see if I could get water for irrigation, and to study the geological formation. The land lies on the north side of Lake Jessup, in Orange County, and it is 16 feet above the lake at high water. There is a slight sandy loam on top. At 3 feet we struck clay mingled with decomposed shell; at 20 feet the amount of shell had greatly increased; at 36 feet and on to 46 there was little but shell, then a strata of blue clay of 4½ feet. Water began to flow, but only a small amount—about 50 gallons an hour. From thence on to 96 feet it was shell and clay. The flow began to increase and all along down from 53 feet I encountered nodules of phosphate rock, black and brown, which rolled under my drill and impeded the work considerably. From 96 feet down shells began to flow out in large varieties—as large as could come up through a 3-inch pipe. They were oyster, clam, muscle, periwinkle, needle scallop, bits of the back of turtle, etc., which looked precisely as though they were just picked up on the coast. I drove the pipe 110 feet and drilled 124, when the water rose 19 inches above the pipe, which was then two feet above the surface. Putting on 20 feet of upright pipe the full flow rose over this. I took off the 20 feet and put on 4 feet of upright pipe and an elbow with 10 feet of lateral. The pressure is sufficient that the water running out of this lateral falls 4 feet ahead of the end of the pipe in a fall of 6 feet. The shells continued occasionally to run off. I have made no quantitative analysis of the water. Temperature is 78° F. There is a trace of chloride of sodium, more sulphate of soda, and some magnesia; also, some sulphurous gas, which quickly disappears in the air. All this tells us how comparatively new Florida is. The cost of this well was about $102; it was put down by hand derrick, four colored men working with us, in four days. The pipe is double extra thick, and probably it was unnecessary to have it so heavy, but safe. This well is for an experiment, when I shall have set a grove, and note results. The timber is remarkably heavy on these lands. Some of the cabbages are 60 inches in circumference and 70 inches to top.

I am satisfied that one-third of the cost of fertilizing will be saved by these wells, and much also in cultivating. The water of my well is light and delicious for drinking. Last winter by steam pump I put 40 pounds of water once a month on trees heavily laden with oranges, and kept it up for four months. There was no stirring of the ground. The trees kept their fruit and looked extremely well on the 15th of September. Those adjoining which had no water looked like overtaxed willing horses, all gone to pieces, discouraged, and broken down.

From Artesia, Brevord County, Mr. J. H. Hogan forwards to this office a clear, concise account of a well at that point. It is located, he says—

> In Sec. 11, T. 24, R. 37, and was let by contract to bore 300 feet at 75 cents per foot. The bore was to be 3 inches in diameter; work commenced about April 1, 1890, and was finished about May 1, being piped down 100 feet, the 3-inch iron pipe drill passing through tough blue clay to the depth of 245 feet, then struck very hard rock 14 feet thick. The progress through this was very slow. After passing this a little water came and at 285 feet a good flow. There was no increase in the flow on drilling 15 feet further; the water spouted 7½ inches above the pipe, the end of which was above the ground. This gave a flow of about 6,000 gallons per hour; the well has been opened for a year and the flow has diminished about 1 inch. I never had any way to pipe up the flow so as to determine the head, and can not tell whether the decrease is caused by sinking of the head or by obstruction in the bore. The temperature of the water is 75° F. No sand or fish have been thrown up. A qualitative analysis made at the New York Homeopathic Medical College gives the following:
>
> Hydrosulphate of soda.
> Sulphate of soda.
> Hyposulphate of soda.
> Chloride of potash.
> Chloride of soda.
> Chloride of lithium.
> Sulphide of iron.
> Alumina.
> Silica.
> Sulphur (in suspension).
> Sulphate of potash.
> Sulphate of soda.
> Sulphate of lime (a good deal).
> Sulphate of strontia (a trace).
> Sulphate of magnesia.
> Bicarbonate of soda.
> Bicarbonate of lime.
> Bicarbonate of magnesia.
> Bicarbonate of iron.
> Sulphureted hydrogen gas.
> Carbonic acid gas.
>
> I irrigated from 4 to 5 acres of land, using hose with small eyelets set in. The land is in orange trees, and the part in small trees planted is partly in vegetables. To lay the ground in pipe with hydrants, etc., so as to use sprinklers would cost for cement pipe from $250 to $300 per acre. Irrigating can not be done by the ditch system in this region; there is no clay subsoil, and little or no capillarity in the soil. No other crop is attempted here but oranges, and a few vegetables in the winter. Clearing the scrub or saw palmetto land costs $75 per acre, hemlock land about $45. As to the value of the land it is hard to say. From $50 to $100 an acre is asked for it.

Mr. E. S. Hubbard, of Federal Point, Putnam County, writes that he irrigates by means of an artesian well, located in Sec. 37, T. 9, R. 27, that is at Federal Point. Drilling began in February, 1890, and well was completed by May. The first flow was struck at 152 and the second at 182 feet. The water is quite soft, with impregnations of iron and sulphur, smelling strongly of sulphureted hydrogon gas, and deposits white sulphur in ditch. Pressure has not been tested. The average rise of wells when closed in that section is about 46 feet above sea level. The flow of Mr. Hubbard's well is 700 gallons per minute, and the temperature is 75° F. There is some decrease in flow, about one-quarter or 175 gallons per minute. The water is sufficient to irrigate 100 acres, but only 30 are now under cultivation thereby. The casing is 6-inch clear for 50 feet, balance in rock. The cost was $5,165 for the 225 feet of bore, which showed the following strata:

Strata passed.	Thickness.	Total.
	Feet.	*Feet.*
Clay	30	30
Quicksand	18	48
Soft sand rock	2	50
Hard clay, several kinds	75	125
Gravel bedded in clay	3	128
Thin strata of limestone	2	130
Soft white clay and gravel, hard brownish-gray clay	10	145
Thin rock gravel and clay	5	140
Gravelly hardpan	5	150
Hard and soft lime rock	10	160
Gravelly clay	8	168
Blue and gray clays	12	180
Very hard and flinty limestone,	2	182
Coralline limestone, hard and soft layers, the water	43	225

The water is distributed by means of drainage ditches which are dammed so as to make them subirrigating. The season is the three dry months of April, May, and June. The original cost of water is the amount given for well, etc., and the annual interest thereon of about $40. The land is underlaid with clay at from 2 to 3 feet from the surface. There is a foot of quicksand between the clay and alluvium. It is very level and requires drainage, hence the use of ditches. The cost of maintenance and repairs will not exceed $2 per annum. Citrus fruits and early vegetables are the products.

J. F. Tenney, of Federal Point, reports one artesian well in use for the irrigation of 8 acres in semitropical fruits. The cost of preparing land for cultivation is about $30 per acre; for irrigation works, it is estimated at $10, and annual repairs at 50 cents per acre, though Mr. Tenney says:

> The work is so irregular and of such varrying character that no just estimate can be given. The plant is so new that the anuual cost can not be truly stated; I can only say that the cost will be nominal.

The well was begun in 1890 and drilling finished in 1891. There were six flows struck, each at 60, 80, 90, 100, 198, and 245 feet. Some sulphur and iron were found in the water, the lowest flow being purest. The pressure is about 15 pounds to the inch. The flow above surface is 23 inches when the well is open wide, with a flow of about 500 gallons per minute and a temperature of 72°. Five horse power is used per each 5 acres. The well is cased for 154 feet, with 4-inch bore. The entire cost $350. The drill passed through sand, clay, coral formation, and thin strata of rock. Water was found in coralline rock about 50 feet thick, of a porous character, and mingled with marine shells.

Mr. J. G. Howes, of Florida, who is living in the neighborhood of Orange Lake, a successful and enterprising orange grower of that State, has a very interesting plant for irrigation purposes. The supply is from a small lake, 200 feet from the pump stand. The method is by sprinkling and wetting from the hose, and manner of use is as follows: The water plant consists of a small pool or lakelet, the water of which is lifted and distributed through the agency of one duplex steam pump, with 8 by 10 steam and 6 by 10 water cylinders, with 8-inch suction, and 3-inch discharge ports. There is a 15 horse power boiler. A 4-inch suction pipe connects the lake with the pump—a distance of 200 feet. The water for distribution is forced through a similar pipe for half a mile, entering the orange grove on the north side and running straight across it to the south. The description proceeds:

> At intervals of 60 feet along this main are placed 2½-inch plugs as hydrants, and when the plant is to be used 2½-inch hose, in 50-foot sections, is attached to one end of these plugs, and stretched out between two rows of trees to the edge of the grove. The rows of trees are 25 feet apart, and two men operate one line of hose. The work of wetting down the trees and ground begins at the edge of the grove, and we will go through the operation with them and then we will know as much about it as they do. The man who handles the nozzle stands in the center of the square formed by four trees, and wets them, as well as the ground between them, thoroughly. As soon as he has wet these trees sufficiently, pipeman No. 2 disconnects that section of hose at the coupling, 50 feet to the rear, and at once begins to water the next four trees; at the same time No. 1 takes the disconnected section of hose and carries it over and stretches it out between the next two rows; he then walks back to third coupling of the line of hose in use, and by the time he gets them No. 2 has got his four trees thoroughly watered. No. 1 then disconnects and begins the work of wetting down, while No. 2 takes his section of hose across and connects it to the section which No. 1 has just laid down, and then he hurries back to the fourth coupling and repeats the operation, and this is continued until the last section of hose is reached, and while one man waters the last four trees the other connects his section of hose to the next plug or hydrant, and then walks swiftly to the end of the new line, and when he reaches the end he finds

the water spouting out lively, and the operation is repeated. Two men will, in this way, water 8 acres of grove per day, and serve from 400 to 600 gallons of water per tree.

The cost of this plant and service is estimated at $3,500. Amount of service rendered is summed up in the statement that it has easily "delivered at the end of 2½-inch hose, more than one-half a mile from the pump, 600 gallons of water in 58 seconds, with a boiler pressure of 75 pounds of steam.

Mr. G. Loutrel Lucas, of Eden, Brevard County, uses for irrigation of orchard, etc., an artesian well, located in Sec. 9, T. 37, R. 50, 41 E., the work on which commenced July 2 and was finished August 25, 1890. The present flow was struck at a depth of 811 feet. Other flows were struck at 700, 760, and 800 feet. The elevation at surface is 13 feet above sea level. The water at 800 feet was strongly impregnated with sulphur, but free from salt. The pressure when closed is 10½ pounds to the square inch. The gauge rises gradually. The rise in 3-inch pipe above ground is 20 feet, temperature is maintained evenly at 70° F. The flow after the well is opened several days remains the same. There is a little fluctuation at times in the flow since the well was first opened, but the average is not less. Sometimes sand is thrown. This is the first report on that head that has been received. The quantity is not large. The inside diameter of casing is 3 inches. The casing extends for 230 feet; the balance being in impervious clay. The cost of the well is stated at $600. Pipe is open at bottom. The following is the record of strata and feet passed:

Strata passed through.	Thickness.		Strata passed through.	Thickness.	
	Ft.	*In.*		*Ft.*	*In.*
Surface sand	3	0	Blue clay	3	0
Yellow golden sand	6	0	Shell rock	0	2
Quicksand, worst kind	140	0	Blue clay	2	0
Cemented sea shell, fine	1	0	Rock	0	2
Quicksand	30	0	Blue clay	1	0
Cemented sea shell	2	0	Rock	0	5
Quicksand	37	0	Blue clay	30	0
Stiff blue clay	410	0	Soft spongy rock like raw cotton	20	0
Medium rock	0	2	Hard rock with clay in holes	5	0
Blue clay	3	0	Water rock, first flow	26	0
Hard flint rock; nine days drilling to get through	0	1	Water-bearing rock	111	0
Blue clay	5	0	Total	811	
Flint rock	0	3			

This well is used to irrigate orange and lemon trees on about 1 acre. Pineapples are also planted between rows. Irrigation is reported to be a success.

Mr. George W. Wilson, of Orange Lake, Marion County, reports about 200 acres under irrigation in his neighborhood. The ordinary means of supply is from small lakes, lifted into tanks or by direct pressure from standpipes, then distributed by hose. The cost of such plant, pipe, 3-inch main, 2-inch laterals, and 1¼ flow from hose nozzle, is about $50 per acre. The annual cost to user per annum is placed at $5 per acre. Mr. Wilson himself irrigates 50 acres of orchard and vegetable land. The product is greatly increased by the application of water. Mr. F. E. Buffum, of Stanton, in same county, reports the use of a small lake supply in the irrigation of 18 acres of citrus land. A weir is used for outflow and a steam pump to lift the water. The main pipe is 2,000 feet in length and of 2-inch diameter, and the tank has 13,000 gallons capacity. The cost of preparing clay land for citrus trees is about $15 per acre. The cost of irrigation plant is not given.

The Orange City Water Works and Irrigation Company, started by Wisconsin investors, is located at Orange City, in Volusia County. It has commenced the work of construction and is expected to be in operation early in 1892.

At Green Cove Springs, in Clay County, a local irrigation company has been formed. The supply will be obtained from a 10-inch artesian well in process of being drilled. Mr. H. B. Stevens, of Citra, in Orange County, reports 200 acres under irrigation, work begun in 1891, at a cost for pump and distributing plant of $12,000. The cost of irrigating truck gardens and orchards at or near Jacksonville is reported as from $50 to $100 per acre. The soil is sandy and ditches are not used. Steam pumps are necessary and also pipes and either hose and nozzle or revolving sprayers are used. There is marked appreciation in Florida of the latter appliance, which is similar to that so largely used and employed for sprinkling city lawns. The largest reclamation scheme for cultivation purposes of which the Irrigation Inquiry has any knowledge is found in the following account of the plans proposed for utilizing the Halpate saw-grass section, embracing over 11,300 acres. It is now under control of the Sebastian Sugar, Land and Improvement Company, which proposes to thoroughly drain the whole area, which now forms an impassable swamp of the extreme headwaters of the St. John River: "At ordinary times this area has from 1½ to 2 feet of water over its surface, but during the rainy season is from 4 to 5 feet deep." The whole country, for from 20 to 50 miles, is nearly a dead level in the rainy season, and the water stands on the prairies 2 to 4 feet deep. It will be necessary to surround the tract with a levee. The tract to be reclaimed is about one-third prairie and about two-thirds saw-grass ponds. It is 6½ miles from the Indian River, famous for producing on its banks the best oranges in the State. The drainage will be into the San Sebastian River, a considerable stream, emptying into the Indian River (which is a tidal lagoon).

> The fall from the ordinary surface of the water in the swamp to tide water in Indian River is 22 feet, and the length of the main canal will be 18 miles, and 54 feet wide on the bottom, 8 feet deep, with slopes of 2 to 1. The total length of the branch canals, including the boundary or intercepting canal, will be 95 miles, without counting the innumerable ditches. The levee will be 60 miles long and 30 feet wide on top, 6 feet high, slopes 2 to 1.
>
> There are three large but shallow streams, some 600 to 800 feet wide, now entering the tract from the west, which will be diked out and a new derivation channel dug for them. The Great Sawgrass lake, 1 mile north of the tract, will be 4 to 6 feet above the water level in the tract when lowered by the canals, and this will have to be kept out by levees and sheet pilling. The slope of the main discharge canal will be such as to allow steamboat navigation.

The soil of these saw-grass ponds is a very rich black mud, 10 to 25 feet deep. From the experience of the Disston Company, who have reclaimed and planted large tracts of this kind of land in the State, it is found to produce abundantly. They have raised on similar land, without fertilizing of any kind, 6,000 pounds of sugar per acre; 30 barrels of rice, worth $3.50 to $4 per barrel; 60 bushels of corn, and are now experimenting with success with tobacco. The soil is peculiarly adapted for all kinds of garden vegetables, which can be placed in the northern markets about February and March. It is also exactly suited for bananas and other tropical fruits, and the drained prairie will raise pineapples, guavas, peaches, pears, mangoes, grapes, alligator pears, etc. Irrigation is to be resorted to after reclamation (drainage) is accomplished, so as to insure crop security.

SOUTHERN ALABAMA.

Prof. J. P. Stelle, of Fort Worth, Tex., agricultural editor of several important southern newspapers, a writer and scientist of ability, acumen, and insight, presents vigorously reasons for the practice of irrigation in coast lands of Alabama. In a recent paper* Mr. Stelle, after alluding in flattering terms to the work of this Department through the Office of Irrigation Inquiry, says:

> In the very near future the most valuable agricultural lands will be such land as can be easily and inexpensively watered, and it don't call for much thinking to enable one to see where this will place the Gulf Coast region east of the Mississippi River.
>
> The region is literally broken up by broad valleys, down which flow perpetual streams of greater or lesser volume. These streams are sustained by living springs and lie in beds but a few feet below the general level of the bottom lands of the valley. There is a first bottom and a second bottom. The first bottom, immediately bounding the stream, is exposed too ccasional inundations, but it is comparatively narrow; the second bottom is above all overflow, and the fall of the stream is usually great enough to throw it upon this second bottom land by ditches only a mile or so in length. The valleys open out on broad expanses of level lands making up the coast proper, and it would be no trouble whatever to irrigate every acre of these lands by turning the streams upon them. Ample water comes down the stream to meet every requirement in that direction if correctly applied.
>
> The cost of putting all these lands under irrigation from Chickasabogue and tributaries would be so small that in California, New Mexico, Colorado, etc., they would consider it scarcely nominal, for there they often carry their irrigation water through ditches, flumes, and aqueducts 30 and 40 miles, and think nothing of it, getting less water than we might get with half a dozen miles of plain, rockless ditch. Now, what would be the outcome of an irrigation arrangement of this kind?
>
> In the first place the system would cost comparatively little. There are no rocks to cut through, and no need of walling. If it was built by a syndicate, that syndicate would first buy up the lands. These lands could be had at from $2 or $3 an acre, but you may put it a little higher on the average if you wish. So scon as the system was complete every acre of that land would go at from $75 to $100 per acre. The irrigation ditches would still remain the property of the syndicate, and the land purchasers would be required to pay a low water rent annually, which could be so shaped as to bring in a good interest on the original investment.
>
> The man who has studied irrigation in the Southwest can easily see what would become of an irrigation arrangement like this. All the lands under the system would be promptly taken and would be converted, as it were, into a continuous village. Churches, schoolhouses, and factories would soon be built, and the now blank and lifeless region would be converted into a very hum of industry. Intensive culture would be prosecuted; fruits of nearly all kinds would be a success, and other crops would be made to lap one upon the other the year round. The early crops would be shipped to Northern markets, as now; the later crops would be consumed or worked up at home. Great canning, evaporating, picking, and central sugar plants would spring into existence for putting the later crops into shipping shape, to say nothing of great spinning and weaving plants to work up the immense sea island cotton product that would certainly be a result of irrigation.
>
> But the best of it is yet to be told. As already intimated the spring crop truck farmer must pay out the best portion of his returns for fertilizers. It is a fact well understood and settled that under irrigation less than one-fourth the quantity of fertilizers as are now employed would go as far to feeding plants as would the whole. The fertilizers now employed to make the spring crop would be ample, under irrigation, for keeping a succession of crops flourishing the year round.

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* Mobile Register, November, 8, 1891.

WELLS FOR IRRIGATION IN TEXAS.

In the progress report for 1890, made to this office and the Department, Assistant Geologist, Prof. Robert T. Hill, of Texas, referred to a successful irrigation work carried on by Mr. William C. Lanham, of Glen Rose, Somervell County, who has profitably irrigated 30 acres with an 8-inch artesian well, which flows about 400,000 gallons of water every twenty-four hours. Mr. Lanham does not use manure and raises staple crops only, such as corn, cotton, and sugar cane. His land is reported to be precisely the same in character as that which produces without irrigation an average of 25 bushels of corn to the acre. The irrigated land gave in 1888, 75 bushels; in 1889, 66 bushels, and in 1890, 40 bushels to the acre. That not irrigated gave from 250 to 500 pounds of cotton seed to the acre. In 1888 Mr. Lanham's irrigated lands gave him 2,200 pounds of cotton seed; in 1889, 3,000 pounds, and in 1890, 4,000 pounds. From ribbon cane he has a regular yield of 350 gallons of sirup to the acre. Several other experiments in the same neighborhood have met with equally successful results. No one has irrigated alfalfa, clover, small grains or small fruits, which are most susceptible of very profitable irrigation. At Paluxy village, 10 miles west, there are two irrigated farms upon which cotton was growing in 1891, 2 bales to the acre.

Enterprises in operation on the Staked Plains region are already demonstrating the possibilities of reclamation. The reports of the artesian and underflow investigation (1890), and of the progress report for 1891, have furnished considerable favorable evidence on this point. There has been a steady degree of progress during 1891, and the use of the phreatic waters for irrigation purposes has steadily increased. A settlement along the line of the Texas Pacific, Martin County, has had quite an experience as a pioneer in coöperative colony effort. The aim was to create small farms devoted chiefly to raising fruits and fine vegetables for early markets. From the outset the irrigation needed has been obtained from nonflowing wells, the water of which, obtained at moderate depths, is lifted to the surface by means of windmills. The objects of the company now operating at Marienfeld is given in the annexed statement:

(1) To grow fruits, vegetables, and general farm crops by irrigation and otherwise for profit. To market the products grown by this corporation in their natural state, as well as to can, pickle, preserve, evaporate, dry, refrigerate, or handle in any method necessary for safe transportation and sale.

(2) To buy and sell fruit and vegetables and to pack for market the produce of others, for a consideration, after the methods enumerated above.

(3) To promote horticulture, agriculture, vine-growing, and general farming in Martin and adjoining counties in Texas by irrigation and otherwise. To acquire by purchase or otherwise, for the benefit of the stockholders of this corporation, parcels of land and to prepare the same for irrigation and to plant the same in trees, vines, and marketable products.

(4) To contract with nonstockholders to plant and irrigate their lands for a suitable consideration.

(5) To make preserves, pickles, and canned goods of every description, and also to make and sell cider, vinegar, wine, sorghum sirup, and manufacture other products of the farm in this line of goods. To erect and maintain the necessary buildings

and sheds for the storage, packing, and preserving, canning, and pickling of fruits and vegetables.

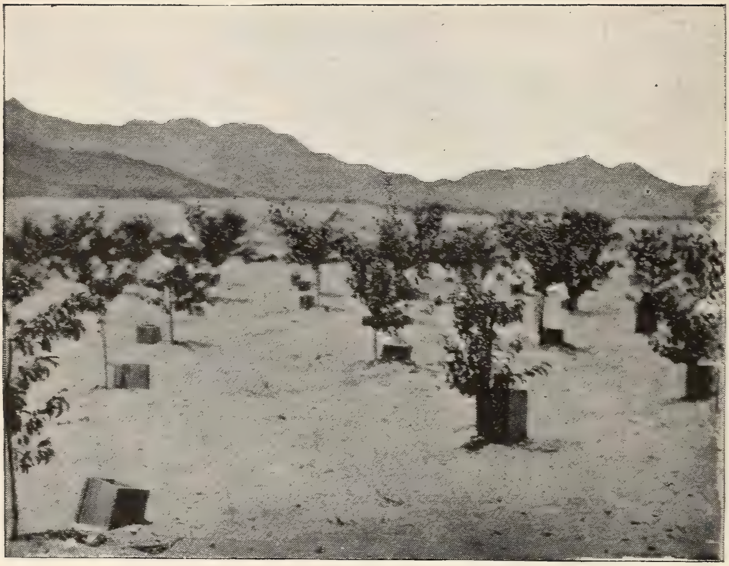
(6) To develop a water supply by means of digging or boring wells, or by erecting dams or tanks; to raise water by suitable pumping machines and to distribute the same by means of pipes, flumes, ditches, storage reservoirs, and other methods; and to secure, and if necessary to condemn in a lawful manner, the right of way for flumes, ditches, and water pipes for purposes of irrigation over lands not owned by this company.

(7) To contract with farmers and others desiring water for irrigation, to supply water in stated quantities for a stated consideration.

(8) To contract with nurserymen, fruit-growers, gardeners, foresters, and others for the establishment of orchards, nurseries, vineyards, market gardens, and forests of useful timber, as well as the establishment of factories engaged in the preservation in various ways of fruits and vegetables or manufacturing edible products of the farm.

There are more than 1,000 flowing wells in Texas, nearly all of them being found west of the ninety-seventh degree of west longitude. Several hundred have been bored during the year 1891. All this data is presented by the assistant geologist and is referred to only to emphasize the interest arising in the extreme South and Southwest over the practicability of utilizing the phreatic waters of that region. Their vast capability and adaptability for making secure an agriculture always rendered uncertain under high temperature, even when the rainfall, if properly distributed, is ample for industrial uses, has just become a matter of general understanding. Prof. Robert T. Hill has recently said in relation to the use of artesian water in Texas for irrigation, that in the development of such wells their use for irrigation was not dreamed of originally, but that now they are being widely utilized. In Somervell County, where rain is rather scarce and one-fourth of a bale to the acre is considered a fair crop, "I have seen," he says, "2 bales of cotton per acre and 250 gallons of Louisiana molasses raised per acre and 80 bushels of corn by the use of artesian well water."

The eastern half of the State is blessed with an abundant supply of rainfall, and hitherto it has been hearsay to say that rainfall was insufficient for agriculture in any part of the State. Sentiment is rapidly changing, however, and the irrigation idea is not only beginning to be tolerated, but applied to a great extent. There is no doubt that the whole agricultural aspect of the western two-thirds of the State, which lies in the region of uncertain rainfall, will be changed within the next ten years, and steps are rapidly beginning to be taken in that direction. The Pecos River in Texas will soon be utilized by the numerous ditches now constructing along its course, and many new canals are also taken from the Rio Grande. The chief area for profitable irrigation in Texas, however, lies in the heart of the State, coincident with the great fertile black prairie region. This area is blessed with one of the most abundant and unique water supplies in the world, consisting of artesian waters and springs. At Del Rio over 15 miles of ditch have been constructed to utilize the waters of a single spring, which breaks forth from an arid plain back of the city and flows a larger volume than the Rio Grande into which it empties. The San Antonio River has its source in springs of exactly the same character, which not only furnish the city water supply, but for 200 years have irrigated several thousand acres in that vicinity. San Marcus, Austin, New Braunfels, Georgetown, and other places have similar natural fountains which would irrigate millions of acres. This water all comes up through natural fissures from a deep source, and the springs might be called natural artesian wells, for wherever in the region characterized by these springs a hole is drilled to the underground supply magnificent artesian wells are



Box Irrigation. Pridham Orchard, Lanoria Mesa, near El Paso, Texas.

Two Year old July Tree. Pridham Orchard, near El Paso, Texas.

secured. Mr. F. E. Roesler, C. E., of Dallas, who has served the artesian and underflow investigation as special agent, and the irrigation inquiry as a volunteer field agent for Texas, has recently declared that—

> The farmer in the Rio Grande or Pecos valley, whom necessity has compelled to farm after rational methods, and who gets just as much if not more money for his wheat than does the ten-bushel farmer, can afford to sell his wheat for 50 cents per bushel and still clear from three to four times as much per acre. The same rule applies to the other crops. Then, again, as the irrigating farmer loses no time in waiting for rains to enable him to plow, he raises two or three crops on the same land while the rainfall farmer raises only one, and that often a small crop in the same time.
>
> Long-headed farmers in Florida and Louisiana where the rainfall is from 54 to 60 inches a year, are beginning to irrigate extensively, and they find it profitable. Some of the growers of fruit in Massachusetts and New Jersey are beginning to learn that irrigation pays. But there are very few of these sensible men. Untold millions of dollars are swept annually into the Gulf of Mexico and the Atlantic Ocean, while other millions are expended for artificial fertilizers.

As a remarkable illustration of what water will do, and also as proving the economic importance of a phreatic supply, the following account of the Pridham Orchard, situated on the mesa about 2 miles outside of El Paso, is given. A personal examination of it was made by the special agent in charge during the summer of 1891. It is 10 acres in extent, planted with peach, plum, and pear trees, with a small portion in vines. This orchard is owned by a stock company and was planted as an experiment. Nothing more uninviting and desolate in appearance can be conceived than the Lanoria Mesa, as it is termed, on which the Pridham place is situated. The system of irrigation is peculiar, as well as original. Water is brought from a well, 122 feet deep, in which the water is raised to the surface by a windmill. The water rises 35 feet deep in the well. The bed rock is 17 feet thick. The trees are regularly set out and at the foot or root of each one is a hollow box or cube of common board about 18 inches in length by 6 inches square. This is set obliquely in the ground near the stock of each tree and vine. The water is discharged from the windmill into a large cask, set in a hand truck. It is then hauled up and down the rows and several gallons of water poured into the box or trough at base of each tree. This it is claimed allows a minimum amount of water to do a maximum of service, it being applied directly to the roots, causing them to grow downward and not spread on the surface as in flooding. Every tree is doing well in the orchard and was doing well at the time of the visit of special agent June, 1890. The soil is about 4 feet thick and is immediately underlaid by an impervious stratum of hard shale. There are several other orchards on this mesa, in which the same plan of irrigation is followed. Edgar B. Bronson, of El Paso, who is in the company operating this orchard, writes as follows:

> That the least cost in 1887 was $35 an acre (unimproved).
>
> That 160 acres of this land sold last month (June, 1891) at $17,000, or a little over $100 an acre (unimproved also).
>
> That the well, windmill, and fencing cost $600.
>
> That the well is a dug well 90 feet deep; there are about 15 feet of water in the bottom, which we have never been able to pump dry or to materially lower.
>
> That a 5-inch bored well would answer the same purpose and be much cheaper and more permanent.
>
> That we have inclosed under fence only about 10 acres, embracing about 2,000 trees, 200 grape vines, and a few berries.
>
> I can not state to you the amount of water in gallons furnished by this well, but can positively that by our experience with the well on the 10 acres now cultivated that it furnishes abundant water for the cultivation of at least 25 to 30 acres in trees and vines.
>
> The trees and vines planted cost $500.

The maintenance of the place costs us for wages and fodder $45 per month.

In the cost of well and windmill is included the price paid for one horse and harness, one cart and one water tank, used for distributing the water in irrigation.

As you have seen, our method of irrigation is peculiar and perhaps original. Immediately beside each tree is placed a wooden box 6 inches square, made of inch boards, 2 feet long and sunk 18 inches in the ground. Six inches above the bottom this box has 2 inch holes bored in it. We put no water on the surface of the ground. The water tank is driven down between the rows of trees with pipe and faucet at rear of tank, and the boxes at either side are filled with water as the cart slowly travels down between the rows. In this way not one drop of water is lost by evaporation or by the saturation of any soil which is not the immediate direct feeder of each particular plant irrigated. Moreover by this box system we carry the water entirely below the roots of the trees and thus foster a downward growth of the roots instead of leaving them to turn upward toward the surface, as inevitably results where irrigation by surface flooding is practiced.

With us of course this box is only experimental, to show the capacities of the soil, and the possibilities in the economies in the use of water. The cost of the maintenance of the place is high, but is a natural result of a condition where we are compelled to pay in cash for every variety of improvement, or stroke of labor bestowed upon the land. We find the irrigation proposition, however to be a sound one, and certainly as cheap, if not cheaper, than a canal proposition, with the added advantage that each individual farmer entirely controls his own water supply.

There are about seven or eight similar orchards and vineyards on the mesa irrigated from wells. I don't know the acreage planted, but should think there are from 10,000 to 20,000 trees and vines growing there.

The most extensive canal system yet operated in Texas is that of the Pioneer Canal system in the Pecos Valley, Reeves County, and adjacent territory on the west side of the river. In the neighborhood of Pecos City, where there also are some twenty-five flowing wells, there are nearly 20 miles of ditch constructed, with 20,000 acres under it. On the east side about 12 miles are completed with over 10,000 acres to be served. When the east side system is finished at least 100,000 can be irrigated. About 12,000 acres were under cultivation by irrigation during the past season. The area is as good for fruit as cotton, for early vegetables and berries as for small grains and roots. It is in the sugar-beet belt also.

AGRICULTURAL HYDRAULICS.

CHAPTERS ON WATER, ITS MANAGEMENT, CLIMATE, INTERMITTENT IRRIGATION, AND THAT OF PLANTS USUALLY CULTIVATED.

[Translated from the French of M. J. Charpentier de Cossigny, by Mrs. A. F. Wood, Office of Irrigation Inquiry.*]

THE CONSTITUENTS OF WATER.

[Chapter I, pp. 6–17.]

Mineral substances in solution in water.—Water never exists in a natural state in perfect purity. In reaching the surface, whether by passing through the thickness of the most permeable strata, or coming from the deep fissures, whence they issue in the form of springs, they carry in solution the various mineral substances which compose the rocks with which they have been in contact during their passage. The substances most common and abundant in water are lime, magnesia, aluminum, oxide of iron, mixed generally with silex and carbonic and other acids. Most of these substances are also contained in the tissues of vegetables and are found in their ashes.

A fact which is evident in acknowledging the presence of these attributes in water is that when the ground is irrigated not only is it benefited by the application of the water to the soil merely, but the water also introduces into the soil the various mineral substances held in solution, to be used by the plants under the most favorable conditions of assimilation. These substances are especially important to the well-being of the soil to be irrigated when they supply those essences which are entirely absent and which would be eminently beneficial. Their absence is often noted. M. Paul de Gasparin has found that water springing from soil reputed to be exclusively calcareous in character has held in solution important quantities of silex.† On the contrary, I have several times had occasion to observe on several localities situated on the same perimeter as Sologne, that when the cultivated ground was completely deprived of lime the water of the springs was highly charged with carcareous salts—a fact which is sufficiently explained by the existence of large deposits of marl contained in the subterranean regions traversed by these waters. Such water used in irrigation not only furnishes an element indispensable to the crops, but, in the long run, even succeeds in improving the character of the soil itself.

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*Second edition, Paris, 1889. Encyclopedia of Public Works.

†Journal of Agriculture, 1872, t. IV, p. 169.

It has been found by M. Hervé Mangon, who has made numerous experiments on the use of irrigation water, that in several cases the mineral substances supplied by the water was in excess of the needs of the crop.

Among these mineral essences are two, which, on account of the universal need of them by all plants and the scarcity of their deposition by nature in cultivable soils, are important, viz, potash and phosphoric acid. Potash does not appear in the analyses of many kinds of water, especially in those of ancient origin, and as for phosphoric acid, there is not a single analysis in which it is mentioned. But we need not conclude from these facts that these substances are positively absent in the generality of natural waters. It must be remembered, also, that it has been but a comparatively short time that these essences have been sufficiently understood from an agricultural point of view, and we must also note the difficulty of correctly calculating and applying the very small quantities of potash and phosphoric acid necessary for plants. To determine these quantities with the requisite nicety would require the use of the most delicate and recent chemical processes as well as the skill of the most practiced experimenter.

However that may be, M. Sainte-Claire Deville has made analyses of the water of the rivers Garonne, Seine, Rhine, Loire, Rhone, and Doubs, and has found that the waters of all these rivers contain potash. Payen has found it in considerable quantities in the water of the artesian well of Grenelle at Paris. From an experiment made by him we may conclude that a field containing 1 hectare (2.47 acres), irrigated with the quantity of water generally used in France,* would receive therefrom as much potash as would be furnished by an application of 87,000 kilograms of stable manure.

It has been demonstrated that rainwater dissolves the potash, little by little, in granite soils. It is equally true that this water also attacks the phosphates found in many soils and especially abundant in rocks of volcanic origin. There can be no doubt, then, of the existence of small quantities of phosphoric acid in most springs and in nearly all rivers.

It may happen that some of the water used for irrigation does not contain a sufficient quantity of these substances for the production of abundant crops; in such cases, in order that all the benefit possible may be derived, this deficiency should be supplied by adding the needed supplementary chemicals, which must, however, be carefully adjusted and carefully administered.

Nitrate of ammonia in irrigation water.—In the before-mentioned analysis of the waters of the rivers Garonne, Seine, Rhine, Loire, Rhone, Doubs, etc., made by M. Sainte-Claire Deville, it is found that matter exists therein in the form of nitrates. These waters, then, with the exception of the Garonne and Loire, contain nitrogen (azote) in the form of nitric (azotic) acid.†

The important influence of nitrogen on vegetation is well known. Water containing animal matter in a state of putrefaction (as in rivers after having passed through populous cities) is notably ammoniacal in its character. Rainwater itself, though the purest of all water, contains, at Paris, according to Barral, from 1 to 3 milligrams of ammonia and nearly the same quantity of nitric (azotic) acid per liter. The water resulting from the drainage of cultivated land is richer in azote than that from springs or rivers, a fact that M. Barral was the first to call attention to.

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* That is, with the quantity of water furnished by a continual and regular flow of 1 liter per second. This quantity would be 15,552 cubic meters in six months.

† Acid formed by a certain combination of nitrogen (azote) with oxygen is known either as nitric or azotic acid. This azote, uniting in turn with lime, potash, soda, forms the salts known as nitrates or azotes.

Gas in solution in water.—Water, especially running water, absorbs air. Gas and vapor are disengaged at the same time, and by means of some quite simple appliances they may be collected and analyzed.

It is well known that atmospheric air is a mixture (and not a combination) of two principal gases, oxygen and nitrogen, in the approximate proportions of a volume composed of 21 parts of oxygen to 79 of nitrogen. Air contains, besides, from 4 to 6 ten-thousandths of carbonic acid gas.

It must be observed that the oxygen and nitrogen, not being in combination, act separately, according to their affinity for the liquid, so that the water is always found to have absorbed, following the proportions of the atmosphere, more oxygen than nitrogen.

We will investigate the rôle played by the gases introduced through irrigation waters into the cultivable soil. Oxygen is not so much a food for plants as it is one of the principal agents in the complex phenomena by which the sap is prepared in the depths of the earth. It slowly burns away the organic matter of vegetable or even animal origin mixed with the soil; it transforms little by little the insoluble matter into a humus which is soluble and which can be easily assimilated by plants. The oxygen, moreover, holds and returns to the soil at need the sulphur found there in a state of sulphates (inoffensive salts), to the exclusion of the sulphurets, especially the sulphureted hydrogen, which last is frequently the product of putrid decompositions, and which is poisonous to plant life. Finally, this same gas—a life-giving agent par excellence—in encountering calcareous or alkaline matter in the soil, causes the azote mixed therein to pass into nitrogenous forms. These azotes or nitrates are the richest and most essential principles in the successful cultivation of the soil.

As yet no experiment has been made determining the exact part played by the water in introducing azote into the soil, and we can only advance arguments in favor of our presumptions. Is this azote finally disengaged into the atmosphere? It would seem probable for that portion corresponding to the water which is evaporated on the surface of the soil under the combined action of the sun and winds. But this is only a small portion of the irrigation, for independently of the limited part which sometimes penetrates to great depths in the earth, there is still another important portion which, after having passed through the plant with the running sap, is returned by transpiration to the atmosphere. But vegetables do not exhale any nitrogen. There is reason to believe, then, that the azote found in solution in that portion of the water of which we are speaking must have become fixed there either by the soil a little in advance of the penetration of the water into the plants through the roots, or else by the plant itself during the passage of the water through it. In the first case it would not have been impossible for a nitrification of the azote to have occurred, owing to the action of the oxygen and the alkaline substances contained in the water before its absorption by the plants. A gas dissolved in water is in a veritable state of liquefaction, and the molecules are infinitely more condensed than when they are in a gaseous state, which considerably augments the energy of the physical force. Who has not noticed, for instance, that the action of the air has no effect on iron nor on most other minerals when they are in a dry state, but that it oxidizes them as soon as water is introduced. Would it not also be possible for nitrogen, usually in an inert state, to become a more active principle when in solution?

M. Hervé Mangon has experimented upon a prairie by irrigating through a whole season. At each irrigation he has measured the quantity of water appropriated and also the quantity which has afterward escaped, not having been absorbed.

He calculated the quantity of nitrogen furnished by the soil by known agents and the quantity found in the crop itself, and found the last quantity in excess of the first. Whence comes, then, this excess, except from the atmosphere, and through what channels, under what influences, and by what chemical aid does this substance penetrate into the earth?

M. Georges has claimed that the azote (nitrogen) is directly absorbed by the leaves, but the truth of this hypothesis has not yet been demonstrated, and it is now generally believed that through the intermediation of the soil and the roots azotic matter passes into the organisms of the plant.

But water contains in solution not only oxygen and hydrogen, but also carbonic acid in various proportions. But the carbonic acid found in the water could not be accounted for by the quantity found in the atmosphere without the intervention of other causes. One of these facts is that the water of the springs is more or less mixed with carbonic acid, and their water is more or less mingled with that of the rivers themselves, etc. On the other hand, Mangon found that irrigation water, running along in narrow channels on the surface of the ground, was found to be much more highly charged with carbonic acid than before its passage through this prairie. Might it not be by means of a similar phenomena that is produced during heavy rains on the surface of each field that the waters of a river are much more highly charged with carbonic acid at the time of high water than at low water?

In any case this acid plays a very important rôle in vegetation. It is by means of it that water attackssolid rocks, sand, clay, etc., and extracts from these inert substances the fertilizing principles which are assimilated by the soil and which improve it. Water, charged with carbonic acid, carries with it in penetrating the soil the instrument whereby valuable substances are disengaged from it, such as potash and phosphoric acid, which would not be otherwise found either in the water itself or in the fertilizer applied.

It is objected that carbonic acid is formed in sufficient quantities in the soil by means of the slow combustion of organic matter, owing to the presence of the oxygen, of which I have already spoken. This objection might have some reason in regard to soils which are very rich in humus, but would not hold when applied to poor soils which contain but little organic matter; and I am inclined to believe that the carbonic acid supplied by irrigation water is useful in most cases.

Solid matter in suspension in water.—There now remains to us the task of examining water from this last point of view, as to the solid particles minutely divided which they hold in suspension and bring along in their course. The quantity of such drift matter is very variable. The quantities of this sediment brought by impetuous torrents rushing down from the mountains is almost unlimited. Pebbles, gravel, and sand are successively deposited in proportion as the swiftness of the stream is diminished, but in the calmest rivers, flowing through the lower valleys, only impalpable matter troubles the transparency of the water. We are at present considering only the ooze or mud, the quantity of which is of course increased in time of floods and diminished at low water.

It has been observed that Alpine rivers, such as the Var and Durance, are muddier in fine weather than in the winter time, owing to the melting of the snow in the most elevated parts of their course; while such rivers as the Seine and Saone, only flowing through plains or low mountain ranges, are, on the contrary, muddier in winter than in summer.

The mud deposited by rivers is a mixture of impalpable sand, clay, carbonate of lime, and other minerals, dissolved into very fine particles; and finally of organic substances nearly always azotic in character. The quantity of these substances varies in different rivers, and even in the same rivers from one day to another. It always happens, however, that the mud deposited by them is analogous to that of the most fertile soils and contains nearly all the mineral elements which are useful to vegetation.

Azote (nitrogen) contained in mud.—The mud held in suspension in irrigation waters and supplied by them to the soil can not fail to add to its fertility. Attention is here directed to an experiment conducted by M. Hervé Mangon on the muds of the rivers Durance, Var, Loire, Marne, and Seine, where we see that even the poorest mud of the rivers Seine and Marne is as rich in nitrogen as stable compost and should be considered as a fertilizer. The Alpine rivers are less rich in nitrogen, but they, also, by means of repeated irrigation, add much of this valuable component of the soil.

Take, for instance, the experiment made on a hectare of land by means of the water of the river Durance and with the quantity of water heretofore made use of in France, viz, 15,532 cubic meters during the six summer months. It is demonstrated in this experiment that the water contains on an average 1.46 kilograms of matter in suspension to every cubic meter, which gives, for the total weight of mud deposited on the piece of land, 23,706 kilograms, which contains from 16 to 29 kilograms of azote, and this is equivalent to from 4,000 to 7,000 kilograms of manure.

AGRICULTURAL MANAGEMENT OF WATER.

[Chapter II, pp. 30–35.]

SURFACE AND SUBTERRANEAN WATER.

Use of rain water.—The cultivator ought generally to occupy himself in collecting and conducting to the most suitable places the rain water, which, when the soil is neither too dry nor permeable, flows off over its surface or runs into ditches or channels. Unless this water be collected in reservoirs it could not be used to irrigate arable lands, which only must be irrigated when there is an insufficiency of rain. But the permanent prairies are benefited, at all times and whatever the climate may be, by slight irrigations as well as those of a more copious character. A meadow, then, in some bend of the land, may be formed by a simple management of the rain supply.

Much depends, however, on the nature of the soil. If it be permeable to a great depth the absorption will be so great that the drains provided for it will be insufficient. If the soil, on the contrary, be very impermeable, the water will run along on the surface of the soil, washing and impoverishing it, and becoming in the process itself more fertilizing. The effects are, moreover, as intermittent as the rain is, Indeed, in a permeable soil lying on one which is is less so, the first rains succeeding a drought will be entirely absorbed. But very soon, if the weather continues rainy, the soil becomes completely saturated, and then, little by little, the water will begin to flow off wherever it meets with the least resistance. Let a ditch be dug in such soil, and at the end of each rainy spell the water will begin to ooze from the sides of the ditch, making a small water course which will fill the bottom of the ditch. In such a locality, in ordinary seasons and under the above conditions, a flow of water can be obtained which if not regular is at least continuous during from five to six months.

The trenches with which the roads are lined and which inclose the fields are generally utilized to receive and conduct the water, but it would be a good plan where one owns the land, in order to collect as much water as possible, to make a ditch beginning below the whole space from which the water is to be collected, not departing much from the level of the soil, but preserving at the same time a sufficient slope to allow the water to flow off freely (3 or even 5 meters per meter if possible). This ditch is often composed of two branches inclined in different directions, starting from two opposite points and uniting at their lower extremities to form the central irrigation channel of the soil to be irrigated. All the other drains stretching over the whole extent of ground to be irrigated lead into this principal ditch.

Use of drainage waters.—This water might be more usefully employed than it is at present. It is usually the custom to conduct the water from the drains, after making use of it in irrigation, into the nearest stream of water, ravine, or ditch. In making a study of drainage one ought first to see if it would not be possible, in disposing of the collecting drains and prolonging them at need, to concentrate all this water in some spot in the lower part of the property to be irrigated. Water thus collected may be used for watering gardens, by gathering it into a reservoir, or it can be utilized in the formation of a permanent meadow, the extent of which would be determined according to soil and climate, and would consist of from 3 to 5 per cent of all the land drained. This, although a small one, is still an advantage.

Use of springs.—The water furnished by springs is often used for irrigating purposes. When there is enough water to supply a stream of water at all seasons it can be used in summer for all kinds of culture and can be applied successively on different sections of ground or be preserved in a reservoir, to be used at convenient times. The waters of several springs, each having a little water but not enough to produce a flowing stream, may be joined together, and so become useful. As to springs of small size, they are especially applicable to the irrigation of prairies, and always below their point of emergence a meadow may be created, with an extent proportionate to the quantity of water.

Location of springs.—The supply of water from springs can often be increased by artificial means. It even happens that a spring is discovered in places where the soil is observed to be always wet, or where sedges, willows, or other plants usually growing in swamps are found; in places where a constant oozing of water seems to be going on, or even in a pond whose water never dries up, but does not flow off either. The work necessary to locate a spring consists in clearing the natural channels which carry off the water of the sand, gravel, trash, and other obstructions; in enlarging these channels a little when they are formed of crevices in the rock which water can not wear away; in obliterating, by means of puddled clay, concrete, or cement, the cracks, the permeable sides of which absorb the spring water in part; and, finally, in combining the small streamlets springing from various sources into one concentrated stream. But the nature of the soil, the disposition of the different strata and mineral substances, the configuration of the land, and the position of the springs may vary infinitely; and for that reason it is impossible to give any positive rules for the location of springs. A provisional channel for leading off the water, so as to work with more ease in a comparatively dry place, is usually provided, but the best way to do this must generally be left to the judgment of the engineer in charge.

When water is observed to be oozing out at the foot of or on the slope of a hillside, more particularly in a little circular valley, the spring is usually located by means of a cut having less inclination than the soil itself, and directed as if with the intention of penetrating the hillside. When the cut is very deep a gallery in the mountain is sometimes reached. In rocks easily worked, and at the same time sustaining themselves without caving in, as chalk, for instance, the piercing of a gallery is not very expensive. These galleries are usually from 0.8 to 1 meter in width and are 1.8 to 2 meters in height, so that the workmen can perform their labor conveniently. When the soil is of a crumbling character and needs to be shored up as the laborer advances, or when the rock is hard and can not be broken up except by blasting, the operation belongs more especially to mining, and becomes of so technical a character as to require special management and to be apparently out of reach of the ordinary agriculturist. Works of this sort are oftenest undertaken in France in order to locate mineral springs celebrated for their therapeutic virtues or those whose water furnishes cities with drinking water rather than for irrigation purposes. Many instances are cited, however, where galleries were hollowed out in looking for water for irrigation. The Moors of Spain and the Persians have thus created little streams, which, some of them, are in use to this day.

In a soil that is nearly flat, or, in other words, in a situation where water can only reach the surface by rising vertically, the vegetal soil must first be removed, and then all the mellow soil through the whole extent of which these oozings occur. The level of the water is lowered as much as possible in these excavations, either by pumping it out or by means of trenches. This done, time must be allowed for the water to settle and become clear, when it will be observed to surge or bubble up in certain places from the bottom, which bubbling is seen much more easily on account of the grains of sand moving up and down; in the absence of the sand light substances, such as small chips, may be thrown in so as to render the motion more noticeable. The position of one of these bubbling points having been determined upon, a little pump well must be made, using a barrel with both heads knocked out for the sides, and this must be sunk above the bubbling point already alluded to. But an ordinary barrel not being sufficiently strong, sections of large trees hollowed out were formerly used for the purpose.

It would be better to use casks with strong staves, made of alder or oak, solidly surrounded by iron hoops, in the form of a truncated cone, which causes the hoops to be tighter. At present large pipes made of compressed concrete, especially used in building aqueducts and culverts, might be used. In every case, the pipe being vertically disposed immediately over the spring, it is sunk into the soil until the upper part sinks below the level where the definite flow of water commences. It is sunk by dredging the inside of the cylinder and directly under its outer walls, at the same time striking it on top with a mallet or putting a weight on it. An iron kettle, the handle of which can be lengthened by fastening it to the end of a stick, will be sufficient to do the necessary dredging. The cask being correctly in place and the interior cleaned out as well as possible, a channel is made at the top of the cylinder for the water to run out at, and the clayey soil is rammed closely all around the cask or well. If this bubbling process is observed in several places the same process is to be gone through with for each place, and afterward the water coming from each one of these well-pumps can be joined into one central ditch. A little basin formed of masonry, or even simply formed of planks, might make the reservoir from which the several ditches flow, and the rest of the excavation might be filled up again. Such is the method frequently made use of in Piedmont, in Lombardy, and in some parts of France.

In other places, instead of casks being sunk which are all in one piece, masonry or stonework is made use of; but this is less convenient, particularly when the work has to be done while the water is there. Springs ought always to be covered with flagstones, as much to keep out the falling leaves and other débris as to prevent the growth of aquatic plants, the latter hardly ever growing in the dark. A little shed might be made inclosing the spring and its dependencies in one close covered chamber, but where the water is only to be used for irrigation purposes this extra expense is usually dispensed with.*

Employment of subterranean conduits for the water of springs.—To collect the water of a given number of springs and to conduct it to the nearest irrigation ditch, numerous kinds of canalization are used. The best way to collect several streamlets near their place of origin consists in forming little channels of masonry, large enough to hold the water without its overflowing. These little channels can either be covered by stones or embankments of earth. Sometimes these little gutters can be joined into a small basin, from whence the water flows directly into a large central ditch, as has already been said; but oftener the springs being sometimes at some distance from the soil to be irrigated it might result in too great a loss from evaporation and infiltration, to say nothing of the filling up with leaves and débris, if only a simple ditch were used. In such a case the various conduits can be directed into one "regard" or flush-box—sort of well pump—in cemented masonry and covered with a movable flagstone. From this "regard" flush-box would start an earthenware pipe, the origin of which would be at a level a little lower than the place of entry for the water; for this pipe being likely to be often full of water, a slight obstruction should be placed above orifice to prevent too full a flow. Earthenware pipes are still in use, as formerly, but care ought to be taken to keep their joints well cemented. It is so difficult to lay these pipes that it is necessary to employ only such laborers as are especially familiar with this kind of work. These conduits, however desirable in other respects, lack elasticity, and the least piling up of the soil may cause them to be ruptured. And then, besides, the small crack would allow a little rootlet to enter, and a network of roots being developed from this small beginning would soon completely fill up the inside of the channel. Engorgements and repairs are more rare in earthenware pipes, and, when motives of economy do not forbid, it would be best to make the pipes of metal. The cement manufacturers of Porte-de-France, near Grenoble, undertake to make conducting pipes of cement, which

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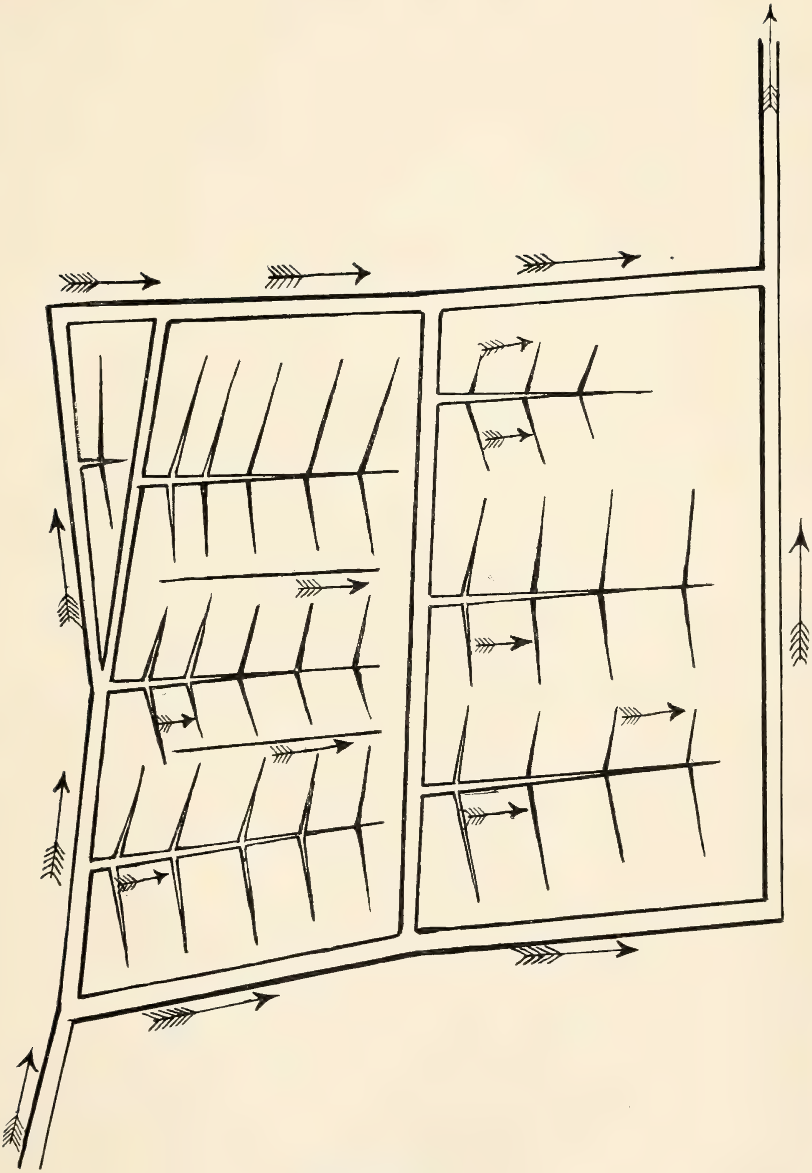
* Indications relative to (captage) location of springs and some examples of constructions raised over springs may be found in "L'Encyclopædia des Travaux Publics, Distributions d'Eau." Bechmann, No. 154.



Spike Channels.

they build in the trenches where they are to be used. Such conduits, except for their small diameters, are more economical than those made of metal; these last rust in the long run, and their defect is the want of elasticity. With that exception, however, they are more durable than those made of metal, which rust after awhile, and offer more resistance than those made of earthenware, which have much thinner walls. To sum up—in many instances very good results have been obtained from their use in various places.

Ordinary wells or bored wells.—There is hardly any locality where, in digging a well, one or several levels of water can not be found, but it is only where the water appears at a depth of from 4 to 5 meters, for instance, that it can be used to advantage for irrigation purposes.

This state of things especially prevails in all plains forming the great river bottoms. There, under a varying thickness of vegetal soil or of mud—more rarely of peat (modern alluvium)—a deposit of gravel is constantly encountered (ancient alluvium), at the base of which is a sheet of water generally abundant, proceeding from the neighboring heights and making its way to the river. Under such conditions it is often profitable to dig wells and extract the water from them, but such water is particularly adapted for gardens, kitchen-gardens, etc.

As to artesian wells, their use in agriculture is much more restricted. This is owing, first, to the fact that the boring of such wells is very expensive, and, in the second place, that their success depends very much upon other contingent circumstances, except in the regions where experiments have already been made or where the existence of a sheet of water has been proven beyond a doubt. Everybody knows of the services rendered by artesian wells in Algeria, in the region of the Sahara.

The results of these borings are particularly favorable when the water gushes out itself at the orifice of the bore. But it sometimes happens, also, that the water only rises to a certain level below the surface of the soil; if this level is not very deep, the work done can still be utilized by the aid of a pump.

DISTINCTION TO BE MADE ACCORDING TO CLIMATE.

[Pp. 19–23.]

Advantages of irrigation in the cultivable lands of southern countries.—It is only in southern countries that irrigation can be successfully employed in all kinds of culture. In the splendid region of the Mediterranean, where the olive is the principal production, notably occupied by Italy, Spain, Algeria, and ten departments of France, the frequency and length of droughts, the persistent heat, and enormous amount of evaporation consequent thereon, make irrigation an imperative necessity in these countries. Some kinds of arborescent vegetations, among which the vine occupies an exceptional place, are the only ones which possess to a certain degree, and in virtue of the vigor and length of their roots, the power to seek at a great distance below the surface for the water which is indispensable to their growth. With the exception, however, of these arborescent species, and in localities where irrigation can not be made use of, in these hot climates only arid land scantily covered with poor crops is to be found. But let water be freely applied in these same localities, (the sun will do the rest), and the scene changes as if by enchantment. A luxuriant vegetation will be sure to remunerate largely both the culture employed in rendering the soil fit for irrigation and the additional labor employed upon it annually.

In northern countries irrigation is especially applied to prairies.—Beyond the limits of the olive region the expense of irrigating is the same, while the advantages derived from it, considered as a means of increasing the water supply, go on diminishing as one advances toward the North. In southern countries, indeed, irrigation is practiced during six months of the year. Moreover, the need of irrigation would only be felt during much shorter periods and at irregular intervals, and there are even certain years during which the amount of water given to arable lands in excess of the natural rainfall would be injurious instead of being beneficial. Thus, in such localities as northern and central France, England, Germany, and Belgium irrigation has been compelled to be confined to special applications and to prairies. Such herbaceous vegetation as is produced on this kind of land accommodates itself more easily than any other to an almost continuous humidity, and even when the water is not needed to moisten the soil, it serves to increase its fertility. Such ground as would otherwise be almost unproductive might be converted into prairies by the application of sufficient quantities of water. In countries rather cold than warm, the herbaceous growth will receive almost as much benefit from irrigation as will the ordinary products of more southern countries, but in a different way.

Can the irrigation of other than meadow lands be successfully carried on except in southern countries?—The question as to whether the methods of irrigation practiced in southern locations can be made use of in more northern climates does not seem to be urgent just now in France, since there is a considerable amount of ordinary dry meadow or pasture land which is easily capable of being improved. All these lands can easily be converted into prairies; land which is either too steep, too wet, or too poor to be advantageously cultivated with the plow; lands which are liable to be flooded, the crops of which are periodically injured by rivers. These lands can be made prairies by first subjecting to a correct system of irrigation, and there will be much work of this kind to be done in France for a long time to come. It seems probable that if canals were constructed in other places as has been done in Provence, Languedoc, and Roussillon, the same methods would be just as successful as they have been in these localities.

The economic solution of this question, then, depends not only on climate, but on the nature of the soil, its configuration on commercial outlets—in fine, on the aggregate of the whole agricultural and industrial régime established in each locality.

The successful system of kitchen gardening adopted in and around Paris shows that, even in the climate there existing, an abundance of water applied to the soil will aid considerable quantities of vegetables, etc., such as lucern, clover, beets, etc., which would, without irrigation, be totally unproductive. This is why Belgium, Flanders, Normandy, and even the coast of Brittany, other things being equal, exceed in fertility any of the central parts of France. This fact is evidently due to the nature of the soil. The Cretaceous or transition soils of Flanders and Normandy are also found in some parts of France. That superficial stratum of mud, anciently called loess, covering some parts of the northern departments of France, is not superior in quality to certain alluvial deposits found in various other parts of the country. The difference in the crops is, then, largely due to climatic influences.

On the one hand an even humidity prevails, permitting the continued growth of beets during the hottest summer months, while on the other hand periods of excessive humidity occur, followed by long droughts, the heat and water arriving simultaneously only in exceptional cases. Flax, which gives such remarkable results when cultivated in northern localities, is extremely difficult to cultivate in the central portions of France. It is owing to the never-ceasing humidity of the northern maritime climates that they support a vigorous herbaceous growth, where as in climates where intermittent droughts prevail the growth of flax, especially, is at times almost entirely arrested, when it withers, its stalks turn yellow, and a product appears which is not only less abundant, but which is *échaudé* or scalded, and the best of which is of very inferior quality.

If irrigation could be made use of during times of heat and drought, a modification of climate might take place and many things be cultivated which can not now be produced. Let us observe that in the Mediterranean provinces, where irrigation has been tried with great success, the temperatures found there do not differ from those of other localities as much as is generally supposed. What distinguishes the climates of the northern from the southern parts of France is that, while on the one hand the winter is long and the summer is short, on the other hand an exactly different state of things exists. It is during the summer, though, that plants attain their greatest development and ripen their fruits. It is, therefore, in such places, in situations where high temperatures are maintained only for a short time, that full advantage of the short duration of the heat ought to be realized by bringing irrigation to its aid.

Irrigation would not, however, remedy the too great abundance of rain at some seasons, or that other scourge, in countries where the plains are far from the sea, the dry, cold wind, which arrests all vegetation by cooling the ground by evaporation, and this evaporation is greatest when the earth is saturated with water.

In fine, outside of the Mediterranean region, prairies, which can be formed anywhere that water can be carried, give generally a larger net profit than any other use to which the soil can be put. But it is probable that, in many locations not naturally disposed for prairies, arable lands, which can be easily watered when necessary and when subjected to appropriate culture, will give results equally satisfactory or even superior. A large portion of the land ought, however, always to be formed into prairies.

INTERMITTENT IRRIGATION.

[Pp. 23–26.]

Irrigation should be intermittent.—If water be indispensable to vegetation, the introduction of atmospheric air into the interstices of the vegetal soil is not less necessary to all cultivated plants. The oxygen contained in the air seems to be one of the essential agents by the action of which the nourishing principles of vegetation are elaborated in the bosom of the soil. A piece of ground constantly saturated with water is a marsh and is only capable of producing rushes, sedges, shave-grass, and other plants peculiar to humid or inundated lands. As to the plants which are of ordinary cultivation, they will languish, wither, and finally die if the soil in which they are grown is deprived for too long a time of the intimate contact of the atmosphere. Thus it follows that irrigation should continue no longer than during the time strictly necessary to moisten the soil sufficiently,* after which that water which is already there will from various causes gradually disappear, and it is only when moisture is again absolutely needed that it should be again applied. The frequency of irrigation must be regulated in proportion to the heat and dryness of the climate and the permeability of the soil. The special need of each plant should be taken into consideration.

Organization of intermittent irrigation.—When a proprietor has complete control of the waters of a stream or canal by means of which his land can be irrigated, he divides this land into fields or parcels and establishes a network of trenches, arranged so that the water can be conveyed to each one of these parcels at will, and they can then be irrigated, separately or successively, by directing the water to those points, one after another, which would seem to need it most.

In cases where the same water supply serves a great number of property-holders, an association or syndicate is formed of those who are the interested parties. The days and hours during which each one has the right to use the water is determined by rule. A rural guard or even an especial employé is charged with watching the execution of this regulation and even, in convenient times, attending to the distributing water gates.

In the plain of Blidah, for instance, there are several canals of distribution with a total stretch of about 30 kilometers (18.58 miles). All along the route of these canals are placed at the commencement of each particular land claim a lateral water gate or sluice leading into an irrigation channel and another water gate serving to bar the canal immediately below the first. The irrigations occur twice a week, one set at night and the other during the day. Each proprietor has a right to the use of the water for a number of hours or minutes, according to the size of his claim. The water starting from a reservoir above and divided into the several canals, runs through the whole length of each canal until it reaches the lowest extremity. The time required to do this is deducted from the time of irrigation. It is the proprietor situated farthest from the starting point that commences to irrigate. When the time alloted to him is at an end, the proprietor immediately above him shuts of the water by means of his water gate and waters his land in his turn. The work progresses in this way, going backwards, to the place where the canal commences, at its highest point, and beginning again in the same way.†

Evacuation of superfluous water.—When an irrigation comes to an end, it is expedient that the surface water shall sink into the soil as promptly as possible, and that after entering the soil it shall penetrate more deeply, and thus cause the suction as soon as possible, which permits the air to penetrate with it to the roots of the plants to be benefited. If there be places where the water might become stagnant these places will be swampy and the vegetation there will inevitably suffer. Thus irrigation should consist not only in conducting the water and distributing it over a certain area, but also in making that area healthy, by providing a way for the superfluous water to run off promptly when irrigation is no longer necessary. This is done by means of ditches of drainage, of salubrity, or of evacuation, so called, either by carrying back the water to a lower point of the same canal which brought it in the first place or in a special canal or to some place where it can run off conveniently. It is often necessary to prepare the soil beforehand. It is only in exceptional cases, where the soil is of excessive permeability or where the irrigation is so managed as to be entirely absorbed before attaining the extreme limits of the soil to be irrigated, that this plan can be neglected. It is through ignorance of this fundamental principle that some persons only succeed in growing rushes where they had intended to improve a meadow or piece of ground by furnishing it with water.

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*Except in certain irrigations of prairies during winter.

†Information taken from an account of the culture of the orange in Algeria, by M. Chas. Joly.

Influence of the permeability of the soil.—In general, whether irrigation has been used or not, the most fertile soils are those which are permeable to a certain depth—0.50 to 1 meter, for instance—and more or less retentive in character at greater depths. This is more important still in case of irrigation. If the subsoil is composed, to a depth of several meters, only of coarse sand, gravel, or other materials which allow the water to pass through it like a sieve, drought is to be feared; besides an enormous quantity of water would be needed to irrigate such lands. If, on the contrary, immediately below the surface strata, whether in grass or under cultivation, only a subsoil is found which is almost impermeable, the space for the roots becomes too restricted, drainage can be only imperfectly carried on, the quantity of water retained after irrigation is too small, and the vegetal soil passes rapidly from a state of inundation to one of extreme dryness. This dryness is also increased by evaporation, which causes too a chilling of the soil unfavorable to vegetation. If, instead, the mellow strata be deeper, a greater quantity of water can be held in reserve, the soil having received more; after the water has ceased to arrive the plane of the water is soon lowered, and the benefit of the introduction of atmospheric air immediately makes itself felt in the space occupied by the roots. The water is not, however, exhausted. In proportion as it begins to disappear near the surface; that of the subsoil begins to rise by capillarity, and maintains a sufficient amount of moisture for quite a long time.

Previous plowing or digging up of the lands to be afterward irrigated.—The preceding considerations explain the fact, already many times proven, that digging or plowing up the soil to a depth of from 40 to 80 centimeters before commencing to irrigate is generally a remunerative operation, whether for the establishment of fields, gardens, or prairies.

IRRIGATION OF PLANTS USUALLY CULTIVATED.

[Chapters III and V. Extracts from pp. 95-189-4-193-4499-202-4-5-6-7-8.]

The cereals.—The cereals are among the number of those plants which only admit of a moderate foliaceous development, which transpire but little, and which require an abundant production of a grain sensibly dry. It might then be supposed that they would need a relatively small amount of water. This supposition is borne out by the observation which teaches that cereals—wheat and barley more particularly—while preferring a fresh and moist soil to any other, can better withstand too much heat than an excess of humidity. It is generally the custom to carefully avoid watering this sort of plants during the time the ear is developing itself and coming out of its sheath, as well as in the efflorescent stage. Corn is the principal cereal cultivated in southern countries, where irrigation is held in esteem. It has been found there that an almost unlimited supply of water can be given during the period of the first herbaceous vegetation—which takes place from the time the seed is sown to the formation of the ear. In countries, too, where it is customary to irrigate in winter, the corn is watered soon after it is sown in the autumn. By these irrigations the fertilizing principles are laid up in the soil, of which they will avail themselves at a later period. They moderate the temperature of the soil during the winter, advance vegetation, and increase the suckers. Later, if the weather be dry, the corn receives another irrigation between the time of the first appearance of the ear out of its sheath and the time of efflorescence. Finally, it is again watered once or twice between the time of efflorescence and the harvest.

In the south of France corn is not watered in the winter time. If irrigated it would be too far advanced, and would be more susceptible on this account to the severe effects of the cold spells always to be guarded against at the commencement of spring. During the other seasons only a limited number of irrigations must be given to the corn, the water being reserved for the more remunerative cultures. Corn is even planted in nonirrigable lands. In this last case, when the ground has been deeply worked and mellowed for the preceding crop, corn, not being affected by drought, is able, without notable accident, to pass successfully through all the phases of its development. It will, however, yield only a product of medium quality as to grain, and of mean development as to fodder (straw). Such a crop is not lucrative, and so corn has been replaced by other kinds of culture—especially arborescent vegetations and the vine—in many departments of France. This is not to be regretted, as there is sufficient land which is still devoted to cereals, and the means of transport for the same are abundant. It is well, however, to find that, at need, crops can be raised in the south of France equal to those produced in the lands best adapted to the culture of cereals; but this can not be accomplished without the aid of irrigation.

It has been claimed that when corn is irrigated the supply of fodder (straw) is increased at the expense of the grain. I think that there is, however, a great deal of exaggeration in this assertion, or, at least, that it only applies in lands where the soil is too light or too poor for the corn. In slightly clayey soils which are also provided, either by nature or by repeated applications of a fertilizer, with the mineral elements necessary for the formation of wheat, irrigation while increasing the quantity of the grain also increases the quantity of the straw in still greater proportions, and it is because the volume of straw is so greatly increased that the quantity of grain appears to be diminished.

Grass prairies.—In the southern departments of France certain portions of the irrigable soils are devoted to grass prairies. The ray-grass of Italy, the tall *féluque* (a sort of grass) grow on them, and sometimes, also, the white clover, and "*lupulines*," besides other grasses. The irrigations indispensable in these climates to the preservation of these prairies are made use of, except during very rainy seasons, from the end of April to the end of September, and renewed as much oftener as the soil when of a less clayey nature dries up more quickly. The intervals between the irrigations should be from 5 days at the least to 18 days at the most; generally 10 days are allowed to elapse between the irrigations. These prairies, supplied each year with fertilizing matter, will furnish as many as three cuttings of forage. The water, generally abundant in winter, is sometimes not applied to them as it ought to be according to the rules already laid down for the irrigations of such prairies.

Lucerne (or alfalfa).—Although it objects to stagnant water and impermeable soils, lucerne is one of the plants which draws the greatest profit from a soil maintained in a constantly fresh condition. There is no doubt that in all parts of France where it succeeds naturally its products might be notably augmented if subjected to such irrigations as those used in the maintenance of permanent prairies. Precautions would have to be taken, however, based on the fact that leguminous plants do not bear prolonged submersion as well as the plants of the grass tribe. The duration of the irrigation should be abridged, and should only be applied to land which can be drained to a great depth, for the lucerne is a plant of very deep vegetation. It could not live where the water was stagnant in the subterranean space occupied by its roots.

Though successfully cultivated all over France, it is nevertheless a plant of southern growth, and it is only when cultivated in a warm country, with irrigation, and in deep soils, that its full value can be appreciated. In the south they do not hesitate to irrigate it frequently. This plant would take the place of the grass-prairies, and advantageously, if its culture were not forcibly restrained by the limited duration of its growth, and if, on the other hand, the grasses were not calculated to prosper in soils of little depth, such as those in which sheets of subterranean water are found; such soils as would not be favorable to the cultivation of lucerne.

When to favorable conditions as to situation are added a fertilizing agent and intelligent care, the lucerne in the south gives four or five cuttings during the year. Irrigation is resorted to from one to four times between two cuttings—in other words, from once a week to once a month, according to the greater or less time during which the soil is capable of retaining its moisture. From 2,500 to 3,000 kilograms are obtained per hectare and per cut, making for the year 10,000 to 12,000 and even as much as 15,000 kilograms of dry forage per hectare, or its equivalent in green forage.

Clover.—If the lucerne is a plant for warm countries, the clover is, on the contrary, the one specially adapted to the most southern portions of the temperate zone. An atmosphere which is habitually moist seems to be one of its principal necessities—and it is a source of riches for Scotland, England, and for the northwestern provinces. In the central part of France it no longer yields a crop comparable with the nature of the soil; as to the region of the Mediterranean, it is very little cultivated (clover), even in irrigable lands. It must be recollected, however, that too great dryness of the soil in that region is injurious to clover, and if it were possible to obtain in the middle zone of France the same means of irrigation already available in the southern zone, it would be interesting to make experiments on the clover especially, as the plant which would be best adapted for such experiment.

Hemp.—Hemp is very extensively cultivated in countries where irrigation is made use of. By irrigation its cultivation is rendered really productive and becomes a rich specialty, particularly in the south of France and of Italy. Hemp is cultivated in irrigated countries exactly in the same way as in other situations—that is—the land is divided into plats separated into paths, which are 30 centimeters in width, so as to allow room for working the plants, and specially for pulling up the male stalks. In order to irrigate thoroughly the plats must only be about 1 meter in width. The walks or paths must be thrown up with the hoe to the depth of several centimeters, and the earth thus dug up will serve to cover up the seed afterwards. In these paths, a little later, the water will be made to run. Hemp loves a soil which is always fresh, and is, moreover, never placed into any but permeable soils; for this double reason it is one of the plants which require most frequent irrigations. On an average it must be watered every ten days, and sometimes even oftener. Unlike many other kinds of vegetation, the soil in which it is planted must be maintained in a state of constant freshness, if not humidity. One must not wait to irrigate again until all traces of the former irrigation have disappeared, but very light irrigations must be given very frequently. Irrigation must, however, be totally suspended sometime before the flowers make their appearance.

Flax.—Flax is to northern countries what hemp is to southern countries. Not only is the dryness of the soil prejudicial to it, but so also is the dryness of the atmosphere. Irrigation has been made use of in the Département du Nord with remarkable success. I think it very probable that generalized irrigation will be the only means of extending the flax region beyond its present limits, which limits are tolerably southern, and have not so far been passed with success.

Arborescent culture.—Trees, as a general thing, are less affected by drought than the generality of vegetation of smaller dimensions, and this is explained naturally when the greater depth to which their roots descend is taken into consideration. Thus the oak, planted in the soil which furnishes the proper elements necessary for its successful growth, traverses with its powerful taproot such soils as it is difficult even for the pick to enter, and which would offer insurmountable obstacles to the penetration of the fine little plants cultivated in our fields. The vine goes deep down into such soils as contain no stagnant water in their subsoil. It is particularly partial to those situations where the subsoil is formed of calcareous rock which is split or cracked; there it insinuates its roots to the depth of several meters into the fissures filled with clayey earth, and extracts therefrom at the same time the mineral food and indispensable moisture. It is then only after persistent droughts have considerably lowered the level of the subterranean moisture that such vegetations would stand in need of irrigation. During ordinary seasons it would rather be harmful to them, for their longest roots having reached a depth where water nearly always exists, it is very necessary that at least a part of the root system of these plants should have the advantage of æration. The fruit trees cultivated in orchards and gardens have not such a deep vegetation as those already cited, but experience demonstrates that the same remarks refer also to them. Fruit trees, indeed, can, at need, support, in the south of France, long droughts mostly during the summer, especially if no vegetables of any kind are cultivated in their shade, and if the surface of the soil is kept always mellow by tilth-dressing applied often. These trees have a more regular growth and are more vigorous and productive when the soil in which they grow can be irrigated when necessary, only this must not be overdone. The subsoil must not be kept for a long time continuously saturated with water in a certain depth under the soil. It can be easily understood how much the nature and disposition of the lower strata of the soil can modify the method to be pursued. The only rules which it is possible to lay down are, that irrigation shall not be resorted to until the drought shall have already penetrated to a considerable depth, that it shall not be renewed until all the water from the last irrigation shall have completely disappeared.

Irrigation is never more serviceable than when administered a short time before the fruit matures; then the water has time to descend to the suckers of the lowest roots. Then a little air enters the soil at the same time, and then the tree is in the best possible conditions at the time when it is about to put the finishing touches to its fruit.

The hotter and more scorching the climate the more evaporation takes place, the more the level of the moisture is rapidly lowered after a rain or an irrigation. Thus, in the north of France, fruit trees would only need to be watered in exceptional cases. On the border of the Sahara, on the contrary, no irrigation is possible unless water can be furnished by an artesian well to irrigate the date palms, which form the oases of this torrid region. In the Algerian Tell and in Spain, all the fruit trees are submitted to regular irrigation, even the vine is no exception. In the south of France irrigation is used more sparingly, and it has been noticed, morever, that all kinds of trees are not benefited by it in the same degree.

The orange.—This tree needs a (fresh) moist soil. If the one where it is planted it does not furnish this condition, irrigation must be resorted to. In permeable soils and also in very warm climates, such as Algeria and the south of France, irrigation is kept up all the year, the plants being watered about every fifteen days during the summer and autumn, and at longer intervals and with less regularity during the winter and spring. In these countries it is only when the subsoil is compact and retains the humidity that irrigation is completely suspended during the rainy season. In those parts of France where the mildness of the climate will permit of the cultivation of the orange irrigation is hardly made use of except from June to November, and even then in moderation.

The pomegranate.—The pomegranate must also only receive a moderate amount of water, or else the fruit will be of little value, small and almost tasteless. It is remarkable that when the pomegranate is irrigated every part of it is developed simultaneously. When, on the contrary, it is not irrigated at all, the outer woody envelope often hardens and soon stops growing. Then it bursts under the pressure resulting from the swelling of the seed.

The mulberry.—The mulberry, cultivated for its leaves, ought to be watered in times of drouth, but with great circumspection. The quantity of water supplied to the soil ought to be less than will be sufficient to bring the plant and its foliage to its highest degree of development. It is known, indeed, that when mulberries have been grown in too moist a soil they produce a large and very tender leaf, but at the same time very watery and not very good for the silkworm to feed upon. In Algeria, in a warmer climate, the same tree is watered all through the winter. These irrigations, while furnishing an abundant provision of moisture to the soil, makes it at the same time more fertile and causes a precocious and vigorous start of foliage. The irrigation must be completely arrested just as soon as the leaf begins to sprout and until the fruiting and pruning seasons are over. Irrigation is then begun again, and its influence, combined with the heat reigning at this season of the year, causes new leaves and buds to push out. This practice would seem to be a rational one.

Often, in the most southern parts of France, mulberries are planted around fields or on the banks of ditches; these last serving at the same as fencing and also as channels for the distribution of water when the soil in which the trees are set is a little higher than the canal. In this case the mulberries are provided with a soil, dry enough to a certain depth, but at the same time having a subsoil which is always sufficiently moist, *Fruit trees in fields.*—Fruit trees play an important rôle in the south of France, where certain kinds are cultivated on a grand scale. Irrigation is sometimes used successfully in some of these fruit cultures. Generally, however, trees which bear fruit in the spring, or at farthest in June, are very little irrigated, the earth preserving up to that time sufficient moisture. Trees which only bear fruit in autumn, must necessarily be irrigated from the commencement of the month of June and nearly up to the time of maturity—such as peaches, autumn pears, and apples. It must be remembered that irrigation is to be avoided as much as possible for all kinds of fruit trees during the flowering season.

The almond is not watered at all in France, nor are the fig trees, except one or two late varieties, which are only found in gardens.

The jujube.—The jujube tree, which bears fruit very late, only gives satisfactory results when irrigated.

The olive.—The olive, which is so valuable in all the countries surrounding the Mediterranean Sea, has a marvelous power of resistance to droughts. It even avoids moist lands, and nowhere gives fuller returns than when growing on hillsides in a permeable calcareous subsoil. It is undoubthdly true that irrigation sensibly increases the products of these trees in the climate of Provence, but it must be used with extreme caution. Before the end of the last century trials were made in regard to irrigation as applied to the olive, on the banks of the canal of Boisgelin, between Arles and Aix, and the results appear to have been marvelous in regard to abundance of production; but the terrible winter of 1789 killed the roots of the olives which had been subjected to irrigation, and it has not been resorted to since. This has not convinced me, however, that a like mortality would have been the inevitable consequence of *all* irrigation. The moderate use of water must be separated from the abuse of it and the nature of the soil must also be taken into consideration, especially that of the subsoil, as well as the periods when the irrigations are applied. Above all, there is in Provence no want of other rich cultures to utilize its soils which are irrigated, while this department is particularly fortunate in possessing such a tree as the olive, which accommodates itself readily to the dryest soils and those which it would be difficult otherwise to utilize. It is certain that in countries still more southern than in Provence, where there is no danger from frosts and which are the true habitats of the olive, this tree has been subjected to irrigation at times, and great advantage has resulted therefrom, provided that the price of water was low enough. Irrigation must commence from the month of December, but always as soon as the olive crop has been gathered. No irrigation must be made use of during the time of efflorescence, which occurs in the month of April, after which water is supplied every time the soil becomes too dry. It is especially necessary to irrigate in September, so as to increase thereby the size of the fruit. Finally, irrigation must entirely cease a little while before the olives mature.

The vine.—Nearly everything said on the subject of the olive will apply equally well to the cultivation of the vine. The same resistance to drought, the same predilection for soils which preserve but small traces of humidity, if not at a great depth, the same abstention from irrigation may be observed in the culture of both vine and olive in all parts of France. The same employment of irrigation as is observed in other countries, especially in Spain (southern), prevails. Near Avignon M. Fancon has lately subjected his vines during the winter to a submersion during nearly forty days consecutively with a sheet of water of a minimum thickness of 10 centimeters above the soil; but in view of the inequalities of the soil and of the partial absorption which might occur an average of 20 centimeters of thickness must be allowed. Not only has this plan of operation appeared to have destroyed the phylloxera, that terrible insect which attaches itself to the roots of the vines, thus putting in peril the vineyards of the South, but the vines subjected to this winter irrigation appear also to be in the most flourishing condition possible. They are vigorous and productive, but must be fertilized every year.

A definite opinion, however, can not be formed on this subject until a more prolonged season of experimentation has thrown more light on it. This submersion must be repeated every year, on account of the near neighborhood of the vines still affected by phylloxera, which have not been submerged.

The soil is divided into compartments by small earth dikes, in order that only the extent of each compartment may be flooded without the necessity of spreading the water over the whole slope of the total extent of the vineyard.

Rice plantations.—Rice is one of the water grasses, and like the reeds it is necessary for its successful vegetation that it shall always have its feet in water. Rice is irrigated especially by submersion. A permanent sheet of water 15 to 20 centimeters in thickness, incessantly renewed by a thin stream of water, is the best method of submersion. But at certain periods this supply of water must be diminished to a sheet of water only a few centimeters in thickness. In certain special accidental cases it would be well to increase this sheet to as much as a thickness of 40 centimeters.

Finally, at the time when the rice is to be worked and at the time of harvest, it must be arranged to have the soil dry, in order to facilitate these operations.

To carry out perfectly the above conditions, the land must be divided into evenly-leveled compartments. Each one of these compartments must be surrounded by dikes nearly 50 centimeters high. As the soil, before the establishment of rice plantations, has generally a certain slope, the lower end of each compartment will be found to have a different level from the upper end. If the whole ground is decidedly level, one or several hectares of extent may be allowed for each compartment; but this extent must be reduced in proportion as the original slope of the ground was more considerable, so as not to have the embankments too high, and also to avoid having too great a height between one compartment and the next. The dike separating the two compartments should be only about 50 centimeters in height, counting from the bottom of the highest one. At the highest part of the dike it must be 66 centimeters wide, which dimension is indispensable for a path of service. A stream of water must then be turned into the highest compartment. From this point the water circulates from one plat to another by means of wasteweirs arranged in the dikes, the sluices at the lowest end serving to drain off the water at will and leave the rice field dry when desired. A ditch must be dug to carry off the water after it reaches the lowest plat; that is, when the water does not run off directly into a running stream or into the sea. All these arrangements are so simple as to be easily understood, and need no further explanation.

Rice plantations can only be carried on in situations where the land is nearly horizontal or has only a very gradual slope. These conditions are often furnished by marshes or by land lying along the seashore. Land of this description, which is of very little use for other cultures, is precisely that which would give the best results if devoted to the cultivation of rice. Those which are slightly salt are not to be avoided, for the water when continually renewed dissolves and carries off the salt as it rises from the subsoil to the surface, and it is even sometimes the means of getting rid of the salt entirely. To this freshening process is added the happy effect caused by the deposit of mud contained in the water used for irrigation, the quantity of which becomes quite considerable in course of time. Thanks to these effects it must be seen that the cultivation of rice in certain unproductive soils makes that soil capable of producing other crops afterwards.

Sometimes rice plantations are carried on one year with submersion, and the next year the soil is put into other crops, without being submerged; and both plans are found to be successful. The dikes would have to be removed the second year, of course, as they would be in the way when the ground was put in order for the other crop; they could, however, be easily rebuilt.

Sometimes a continuous stream of water is not required in cultivating rice, and only supplied during certain periods, as in other lands devoted to irrigation. If necessary, rice planting can be carried on in this way. In such cases the water is left standing for several days, when it is again administered.

This method is very inferior to that of applying a continuous stream of water, as then the rice plantation is always invaded by a great abundance of adventitious plants, and is more unhealthy than when subjected to a continual stream of water.

Rice plantations are essentially unhealthy, and are supposed to cause the prevalence of intermittent fevers, and can be prevented by no management nor hygienic conditions now known, whatever may be said to the contrary. In the mud which covers the soil myriads of insects and animalculæ are moving about. When the water is turned off the rice fields this soil dries little by little in the scorching rays of the sun. The plants with which it is strewn, the animal life, and especially the infusoria which pervades the soil, die, and cause a putrid fermentation. This is, probably, the cause of the evil.

If there were sufficient movement of the water, or if the rice could be worked and harvested under water without ever completely turning the stream, it is possible that this unwholesomeness might be overcome.

It might be found that, on lands which are alternately submitted to inundation and drought, the insalubrity might even be found to exist to a greater extent.

Quantity of water required for a rice plantation.—It has been calculated that a continual stream of water of 1½ liters to 2 liters per second and per hectare is necessary for the establishment of a rice plantation; but there are many times when a greater quantity might be required.

IRRIGATION BY ARTESIAN WELLS IN ALGIERS.[*]

[Translated for the Office of Irrigation Inquiry.]

M. Daubrée has drawn attention to the notes on artesian wells in the provinces of Algiers, Oran, and Constantine, which have been published by M. L. Ville, general inspector of mines. Besides the native wells which have existed for centuries—especially in the Sahara—to bring water and fertility to many parts of it, a great many wells have been bored by more perfect methods. It is but fair to mention the initiative taken as long ago as 1844 by M. Henri Fournel, at that time chief mining engineer, showing the utility of a chain of wells to be established between Biskra and Tourgourt. Soon afterwards, in 1848, M. Dubock, mining engineer, established one in the neighborhood of Biskra, under the patronage of General Desvaux, who has not ceased to encourage in the most active manner other borings of the same nature. From that time up to 1875, 615 wells have been bored, of which 404 are in the province of Constantine, 194 in the province of Algiers, and 15 in that of Oran. These wells belong to different basins, and these basins are subdivided into other distinct basins. Thus, in the province of Constantine, the great basin of the Sahara incloses 104 wells, divided into three basins; the richest in wells is that of the Oued Bir, to which belongs the oasis of Tourgourt.

Among the diverse basins of the province of Algiers is included that of the plain of Metidja, which is subdivided into 4 basins inclosing 80 bored wells.

The total length of the borings is 26,352 meters (86,456 feet). The total cost has aggregated 2,497,780 francs ($499,558), which gives an average of 95 francs to the meter (nearly $19). Most of these wells have been bored in old alluvial soil, in Quarternary deposits or in Tertiary beds.

Among the most interesting facts may be mentioned the increase of temperature, which in the borings of the "Grand Lac" rose to 57.59 feet; now the average increase is one to 98.4 feet. This is a very rapid increase, of which, however, there are other examples. Some of these waters are charged with saline matter.

Discussing the origin of artesian waters in the Sahara of French Algiers, M. Jahcle, army chemist, stationed at Biskra, Algiers, published the following interesting statement in the "Journal de Pharmacie et de Chimie" of August 1, 1889 (page 102).

M. Paul Leroy Beaulieu, in his work, "L'Algérie et la Tunise" (page 146), says:

"There is yet another work to which the French administration has applied itself with most brilliant success, and which is capable of still greater developments, and that is, the artesian wells. This work has been the means of creating oases, and may yet extend cultivation to the extreme south. A Russian publicist, M. de Tchihatchef, who has recently (1880) made Algiers a study, speaks of it with enthusiasm, and esteems highly the importance of the results which we have obtained. He writes:

"Between the Chott Melghir and the town of Tougourt, a distance of about 120 kilometers (78 miles), there are not less than 40 artesian wells, which is one well for every 3 kilometers; and doubtless this line of wells will be continued as far as Ouargla. At present, between Tougourt and Ouargla, a distance of 150 kilometers (93 miles), there are but 5 artesian wells.

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[*] Bulletin des Séances de la Société Centrale d'Agriculture de France. (1876.) Page 464.

"The Russian author estimates the number of wells bored in the province of Constantine, a subdivision of Batna, from 1856 to 1878, at not less than 155. He says: 'The number of borings for bubbling water is about 149 and for ascending water 262; the total depth bored is 18 kilometers, 626 meters (61,108 feet), and the primitive discharge of the bubbling and ascending sheets is 182,119 cubic meters every twenty-four hours, or 765,742,969 cubic meters the year.'

"These figures are sufficiently eloquent and need not be commented upon, and when it is considered that they represent the work of only twenty-two years, it can be said that if France has given Algiers nothing else but these artesian wells, they alone enable her to compare favorably with no matter what other country.

"Since the Russian author has written these lines French activity has not slackened in its exploitation for subterranean sheets of water. On the 31st of December, 1884, the number of artesian wells in the three Algerian departments was 257 bubbling and 419 ascending wells. The total depth of the borings was 27 kilometers, 897 meters (91,525 feet), 50 per cent more than the figures given by M. de Tchihatchef."

The few Europeans who have ventured into the region of the bubbling wells south of the department of Constantine have interested themselves concerning the origin of these undrinkable artesian waters. The hypothesis of an interoceanic current is now held to be untenable, as chemical analysis shows that the composition of these waters has nothing in common with sea water.

The greater part of this section of the Sahara is below the level of the sea, and being bounded on the north by the Auris Mountains has led to the general admission that the artesian waters arise from the infiltrations of rainwater in the Tell River and the high plateaus. We will examine what truth there is in this. A careful study of the artesian waters of the region of Tourngouth-Ouargla will enable us to understand—

First. That the hydrostatic level of these bubbling sheets of water is higher in proportion to the depth of the sheet.

Second. The discharge of artesian sources increases with the depth of the sheet.

Third. The quantity of salts dissolved diminishes as the depth of the sheets increases. In waters which have been analyzed up to the present time this quantity varies from 4 to 15 grams=60 to 225 grains.

Fourth. The weight and grouping of these dissolved salts do not vary much with the seasons nor with the years.

Fifth. Sulphate of lime dominates in the artesian waters, and in decreasing order the alkaline chlorides, the earthy carbonates, etc.

Sixth. All artesian waters contain nitrates, without applying to these salts the rule in paragraph 3. Sometimes there is more nitrogen found in a lower than in a higher basin, and again inversely (nitrogen in a combined state of nitric acid), but generally the proportion of combined nitric acid does not vary much in these artesian waters.

There is no current, since the waters are not all of the same composition. They are solid, located in natural superimposed reservoirs, and separated by layers of impermeable limestone.

A knowledge of this phenomena controlling these bubbling waters enables us to determine their origin, and it is not believed that they can come from the calcareous mountains to the north.

In the first place the waters of the Tertiary Algerian strata and of the fossilized limestone of the Auris Mountains mostly contain alkaline chlorides. During infiltration and passage into the Quaternary basins, they preserve these salts in dissolution; now, the proportion of chlorides which is found in artesian waters is from four to five times less than that which exists in the waters descending from the Auris. This fact is also applicable to the carbonites. The waters of the Auris contain but few sulphates; it is true that while infiltering into the Quarternary strata they might get charged with sulphates; but there is no reason why quantities of other dissolved salts should diminish so considerably.

In the second place, the department of Constantine and the extreme south does not contain any deposit of nitrates, nor do the waters of the high plateau on the Mediterranean side of the south side of the Auris contain nitrates, unless accidentally. These waters infiltrate themselves into the Tertiary strata and reach great depths under ground, without any contact with the air or nitrogenous matters. Therefore, the basins of the Sahara can not get so charged. If the artesian waters come from the north, how can we explain the presence in them of the combined nitric acid?

Formerly there existed at Biskra some military saltpeter works. Little hillocks, formed by the remains of ancient Arab villages, built in pise (pounded earth and shell), furnished the nitric earth; but independently of these, nitric beds alone are used here.

Everywhere where the waters produce these efflorescences by evaporation, which often spread over many miles, nitric acid in a combined state is found associated with the sulphate of lime and the alkaline chlorides. Not only do the nitrates exist in the water of the Oueds, but they are also found in the sheets of water caused by infiltration, which are not bubbling but on the surface. Such is the sheet of the Zibans, a fortune to twenty oases, which, by its influence, are covered with magnificent date-palm trees.

Returning from a mission to the Sahara in 1861, Mr. Ville, mining engineer, published the analyses of the waters collected by him between Bonê, Ouargla, M'zat, and Algiers. He drew attention to the presence of the nitrates in the potable waters of the country of Mozatites. The fifth of the natural salt found in these waters is the nitrate of soda. This is remarkable and could not fail to be observed. As to the origin of this nitric acid Mr. Ville says:

> The presence of these nitrates is probably owing to the electric state of the atmosphere during violent thunderstorms, which occasion the floods that fertilize the oasis of Beni-M'zat.

However, this explanation of Mr. Ville does not seem admissible for two reasons:

First. The thunderstorms of the M'zat are neither violent nor frequent enough to manufacture, with the nitrogen of the air, the composite nitrites which are found in the water. If the nitric acid is produced in the atmosphere by the electric fluid acting upon the nitrogen of the air, and upon the ozonized oxygen, it is by the vapor of the water condensed into rain, so that the acid is formed and taken into the soil. Now, in that part of the Sahara of Constantine during some years there is not more than 2 inches of rainfall, so that can not be the origin of the permanent nitrates, especially as in the Tell and the Auris the thunderstorms are more frequent than in the Sahara, and yet the waters of the Tell do not contain any nitrates.

Second. The fluvial and artesian waters of the Sahara when analyzed are found to contain the same quantity of nitric acid, no matter when the trial is made, whether during the seasons of thunderstorms or at any other time.

The waters of Oued Biskra and the Oued Bir have the same composition to-day that they had in 1861. The discharge of the sources of the

Oueds may have varied, but the proportion of the salts dissolved in the water has not changed any more than the soil from whence the waters are derived.

The presence of nitric acid in the atmosphere during thunderstorms is of little moment, but the presence of artificial saltpeter works, like those of Biskra, is a rare fact accidental in the Sahara. The presence of these nitrates is general in the waters of the south; in the waters which flow through the inhabited oases and also in the wells of the desert, far from all animal life.

We think that the clayey alluvium of Chott Melvir (the ancient sea of the Tritons), like the gypseous sand of the quaternary strata, possesses in the highest degree the property of continually setting free the nitrogen of the atmosphere, even outside of all vegetation.

Third. The presence of these nitrates in the artesian waters prove their origin. The waters come in great part from a quaternary formation.

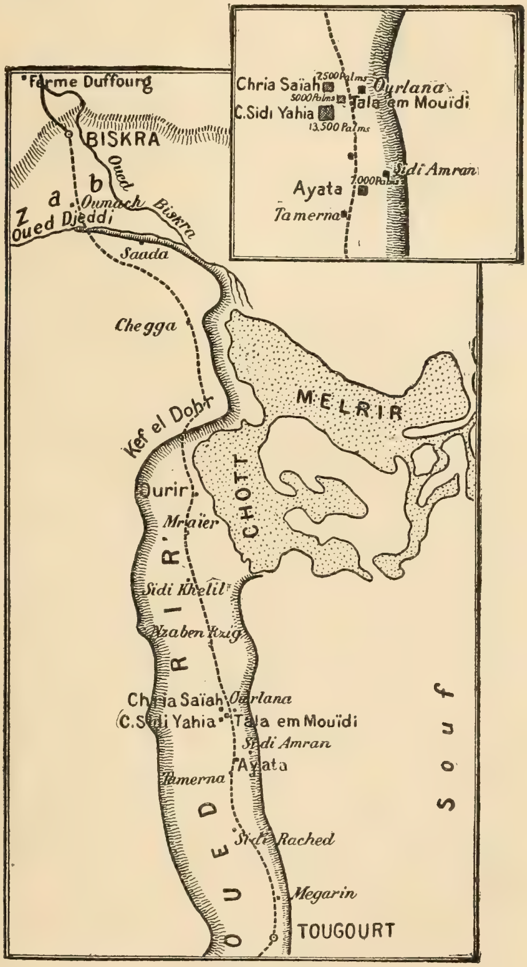
These infiltrations take place naturally at high altitude. This, during the infiltrations from the surface and in the shallow beds of the soil, shows that the water is charged with the nitrates. The dissolved salts penetrate the lower basins and when the artesian bore causes the water to recover its hydrostatic level, the nitric acid is combined in the same proportions as in the water which flows up in the original surface above.

Recently the attention of the civilized world has been called to the organization by Cardinal Lavigerie, of Algiers, of a Catholic order to aid in the suppression of the African Arab slave trade, with its terribly destructive raids, its wholesale slaughters, deportations, and sales. The headquarters of this order has been established at Biskra, on the South-Algerian borders of the Sahara. Quite a large number of affiliates are already there, and the place was consecrated in March, 1891.

The name of the spot is M'salla, which is the Arabic designation for "a place of prayer." The estate contains a plantation of palms in full bearing, and is traversed in part by a small irrigation canal, bearing its share of the precious fluid from the neighboring town to which the area is entitled. Great stretches of ground, however, are uncultivated for the want of water, and measures have already been taken for its reclamation by the creation of a further artificial supply. A well was sunk to a depth of 53 meters (over 163 feet); the water, declared to be practically inexhaustible, rises naturally to within 32 meters (105½ feet) of the mouth of the well, and is thence raised by pumps to the surface. A second well has also been dug, in order to provide temporary auxiliary resources. The militant monks will therefore be trained in the methods of Saharian culture, as well as in the use of arms. The house, occupying an area of 70 meters by 10, with the kitchens and offices in outbuildings, has the ground floor solidly built of stone instead of the sun-dried mud bricks generally used by the Arabs. The choice of Biskra for the headquarters of the order is a fortunate one, for the town, which is situated in an oasis, commands one of the principal routes of the Soudan. The town proper, is composed of one large street built of European houses, and intersected by a number of smaller streets. The oasis, which is five kilometers long and half a kilometer broad, forms a forest of 150,000 palm trees and 5,000 olive and fruit trees. The population is cosmopolitan, and includes French, Tunisians, Arabs, Moors, and Israelites.

Napoleon Ney, a French engineer ("The Proposed Trans-Saharian Railway," in Scribner's Monthly for November, 1891), says:

> To a young civil engineer, M. Georges Rolland, belongs the credit of reawakening the idea, long dormant, of a trans-Saharian railway. M. Rolland, who had been concerned with one of the Saharian expeditions, as I have already mentioned, made the subject of a desert railway his constant study. He established in the Sahara of Constantine an excellent colony, and in the desert regions of Oued Rir, between Biskra and Tougourt, he introduced a system of irrigation that has transformed the desert into a rich and profitable oasis. The ocean of sandy desert that separates the Soudan from Algeria has been cited by critics of the trans-Saharian scheme as an insurmountable obstacle. And yet no one considers the Atlantic waves as an insurmountable obstacle to the exchange of commodities between the new and the old worlds. I can say that the trans-Saharian railway will bring fertility with it. With sand and water one accomplishes wonders in Africa. The Arab proverb runs: "Plant a stick in the sand and water it, you will have a tree." The name Sahara is not always synonymous with desert. Notwithstanding the dryness of the climate, the Sahara has running water courses in summer, and subterranean lakes and artesian wells too deep for surface evaporation. In the Saharian oases, where water



[From Scribner's.]

reaches the surface naturally, date palms make real forests and shelter smaller vegetation that shows a grateful green against the monotonous gray of the desert. The date palm grows in the most arid soil, gypseous and even saline, sandy, and stony. The palm needs heat and water—its head in the burning sun, its feet in the water. It is the chief resource of the natives of North Africa, the king of the desert of Sahara, the tree of the Bible. The date is to the Sahara what wheat is to Europe, and rice to India and China. It is the common food of the native and his surest friend. It is the chief wealth and commodity of barter of millions of people, and is exported to every country. Its use is growing in Europe and America. When it can be used as a common fruit and not as a luxury, its value will be still more apparent. The date palm fruits in eight years after planting (and sometimes in five), and its culture is profitable. With 200 trees upon a hectare (about 2½ acres) it brings in more than 1,000 francs a year. It will be seen that it is as profitable to plant palm trees in the Sahara as grapevines upon the slopes of Algeria or in the south of France. Its fruit is slower in coming, but there is no phylloxera to be feared.

I have spoken of the subterranean sheet of water under the Sahara. The results produced by the artesian wells sunk since the French settled in Oued Rir, a series of oases south of the province of Constantine, of which the chief town is Tougourt, are nothing less than marvelous. The wells of the natives, lined with wood, last but a short time owing to the filling up of the sand, and everything dies for lack of water. For this reason some of the oases have disappeared under the sand. The natives were discouraged. "Our children are weak," said one of the chiefs. "If God, the worker of miracles, does not help us, in ten years the Oued Rir will be deserted, buried in the sand." As in the cases of the deserted cities of Central Asia, to be found on the line of the Trans-Caspian road, the Oued Rir was about to die of thirst. But the miracle was accomplished, and French engineering was about to save Oued Rir. On January 19, 1856, a memorable day, the sand-drill of the French engineer, Jus, brought forth a splendid stream of water, 4,000 liters (888 gallons) a minute, to the astonishment of the assembled natives. The Fountain of Peace was the name given to this well. The sand-drill won a greater victory and accomplished more than war for the peace of the Sahara. Since then the drilling in the Oued Rir has been continued with energy and perseverance by the military authorities under the direction of M. Jus. On October 1, 1885, there were 114 artesian wells belonging to the French and 492 belonging to the natives. Counting the few natural supplies of water, this gives a supply of 253,678 liters (56,372 gallons) of water a minute, or about 4 cubic meters (141 cubic feet) of water a second, equivalent to one-tenth of the flow of the Seine in summer, or equal to the flow of several streams large enough to give their names to departments, such as la Vilaine, le Tarn, l'Avignon, and la Dordogne.

Thanks to the success of irrigation, the oases have become fertile again. There are to-day forty-three oases in the Oued Rir, 520,000 date-palms in bearing, 140,000 palms of from one to seven years of age, and about 100,000 other fruit trees. The annual production of dates is valued at more than 2,500,000 francs. The wealth of the Oued Rir in gardens, wells, houses, etc., has increased fivefold in the thirty years that have elapsed since the first well was drilled. In seven years, 1882–1889, M. Rolland and his associates have "created" oases and three villages—at Ourir, in the north of the Oued Rir, at Sidi Yahia, and at Ayata, in the central region. They sank nine wells, which give a flow of nearly 23 cubic meters (812 cubic feet) of water a minute. About 400 hectares (988 acres) of barren land have been made fertile. They have planted the enormous number of 50,000 palm trees, of which a fourth are of a fine variety known as *deglet noir*. They have dug 90 kilometers (56 miles) of irrigating ditches and have built dwellings for the French agents, the native laborers, storehouses, etc. A distinguished French engineer, M. H. Tournel, has well said that when one sees the amazing transformation produced upon the soil of Algeria by artesian water, the thought inevitably suggests itself that the conquest of the land has been achieved by first conquering what is under the land.

FACTS AND CONDITIONS

RELATING TO

IRRIGATION

IN

VARIOUS COUNTRIES.

PREPARED BY

RICHARD J. HINTON.

IRRIGATION IN NORTH AND SOUTH AMERICA.

MEXICO.

The principal crops grown in Mexico with the assistance of irrigation are sugar, coffee, corn, wheat, oats, barley, beans, cotton, and tobacco; also oranges, bananas, and other fruits. Without irrigation, except near the coast, the yield would be very meager; with irrigation said crops are excellent, and will compare favorably with those of other countries, especially when consideration is had of the primitive agricultural implements used and the inefficient cultivation, as contrasted with that practiced elsewhere. The water supply is generally from streams, springs, and lakes. Some of the springs are large and important. One of these is on a hacienda belonging to the descendants of Cortez, in the State of Morelles, which supplies irrigation water sufficient for a fine sugar plantation.

Storage and distribution works consist of dams, intended to elevate the level of the water in streams and rivers; also large reservoirs are formed by means of massive dams, generally of stone, the water being collected during the rainy season and held for use when needed.

Each State of the Republic has its separate laws and regulations regarding the distribution of water. The duty of water per acre and the amount used per season per acre vary according to soil, climate, and plants under cultivation. Moreover, the cost of water is generally included in the rental paid for the lands, which varies exceedingly in different places, according to the circumstances attending each locality. The ownership of the water is both public and private, but generally the latter, as the water privileges, being considered of quite as much importance as the land itself, have, in many instances, been transferred or transmitted by inheritance along with the title to the land.

The following decree as to water management, approved June 5, 1888, is printed in the Consular Report on "Canals and Irrigation" (1891), issued by the State Department:

ART. 1. There shall be considered as general public highways, besides the inland roads, railways, etc., to the effects of section 22, article 72 of the constitution, the following:

The territorial seas, marshes, and lagunes situated on the seacoast; canals constructed by the Government or by means of public money; interior lakes and rivers, if navigable; whatsoever lakes and rivers situated and serving as boundary lines between the Republic and foreign nation or between two States.

ART. 2. The federal executive has the power and right to look after the aforenamed general roadways, and to regulate the private and public use thereof according to the following basis:

(1) The towns situated on the seashore or the banks of a river shall have the gratuitous use of the water necessary for all domestic purposes of its inhabitants.

(2) There shall be respected and confirmed the rights of private individuals relating to the use and profit of rivers, lakes, and canals, providing that said rights consist in lawful titles or civil prescription exceeding ten years.

(3) The concession or attestation of rights or titles to private parties on the lakes, rivers, and canals, relating to the present law, can only be made by the department of public works, excepting the case when said concession shall change the course of the rivers or canals aforenamed or should deprive of the use of their waters the inhabitants living down the stream.

(4) The rights of fishing and pearl diving on the territorial seas and the uses and profits of marshes and lagoons situated on the seashore or national vacant lands shall be regulated specially by the executive power.

ART. 3. All transgressions of law comprised in the common jurisdiction committed on interior lakes, canals, or rivers, as well as the controversies that may arise between private individuals relative to obeying the statutes issued by the department of public works, shall be submitted to the competent local jurisdiction.

A small number of wells, comparatively speaking, are in use in Mexico for irrigation purposes, the water being lifted generally by windmills. There are some small artesian wells along the railroad lines. Of the State of Coahuila, Consul Wœssner, of Saltillo, says that—

Water is worth a great deal more than land in this country, and the right to use it is fixed by law. There is considerable water power unused, which according to law can be acquired by denouncement. If a spring of water arises in the land of any one, the owner of the property also owns the spring. Rivers are owned and controlled by the State through which they pass. Rights and privileges to public waters are sold by the State. The system of water distribution is as follows, and is generally acquired by purchase:

A stream of permanent water is called thirty days of water, and the owners may sell the right to any one to use this water for any length of time, say, for example, one day in every month, which is called one day of water, worth very often as high as $1,000 a day. It is an understood right between all landowners that parties owning any right or privilege in the water can pass the same to their lands through the lands of adjacent owners by means of narrow ditches.

This system often causes many difficulties, particularly when the owner of a day or two of water dies and leaves some fifteen or twenty heirs, each of whom receives his share in hours, being an equal division, under the same right, of the day or two of water inherited. The formation of artificial lakes has already awakened attention, and a foreign (American) company of capitalists agitates at present the question of making a lake with the waters of the Rio Grande, to be used for industrial and agricultural purposes. This project, however, involves difficulties arising from its international character.

In all railroads and public highways provisions are required for the passage of irrigation ditches, pipes, flumes, or other modes of conveying water. A law under date of February 14, 1856, controls and regulates the distribution and measurement of water. The unit of water is identified with a furrow, and is termed the "surco" or "selco." The metrical system was introduced in 1857, and the liter (0.26417 part of a gallon) became the legal unit of measurement. The old system is still recognized when embodied in deeds and law papers. An elaborate code of regulations—handed from the Spanish control royal instructions regulating "servitudes of water"—has been promulgated in 1754. The guiding principle, both as to land and water, of these instructions was that all such property inured in the Crown and for public use and benefit; water rights were conceded to individuals as a special favor from the Crown. The law provided that to the sovereign and to no one else appertained the right to distribute natural waters. This is still the controlling principle, of Mexican law. The character of streams and other water sources was defined as follows in 1754, and the rule still controls:

A torrent is a sporadic stream, originating from snow melting or sudden rainfall.

Rivers are public and private. In the first all enjoy equal rights; in the others some special contract or arrangement regulates use—it is usually described as having "no banks." Banks indicate in law the precise course of the flowing stream.

Concessions of water make the same an appurtenance of the land through or over which it flows.

A servitude is property pertaining to the thing. As to water, it attaches the same as service for land. Two predial estates are involved; one is entitled to use of water on another person's land, the other is recognized as liable to such servitude. There are both urban and rural servitudes. The latter involve the right to convey and use from another one's land water irrigation, domestic, stock supply, and for mill purposes. Works damaging others may not be constructed. Damages will be given for use of right of way. Stream courses may not be altered to the damage of those below. They may be changed on one's own land, if no harm is worked for others. Springs can be used by others than landowners for only a certain number of hours per week.

Measurements for distribution are made according to position on the line of supply. All works must be of area easily calculated. Measuring gates are required. Flows must be continuous for a certain time, or when intermittent must be regulated. In fine, the rules are minute, involving all details of distribution. Cost of works are levied pro rata upon all lands served. These works must be constituted to known laws. Owners of springs or fountains or of flowing wells can control them fully. Surface waters become the property of the landowners in twenty years after possession, if he construct works subject to the "servitudes" of others. The flow and distribution from upper to lower levels is regulated by the water laws. When the supply is insufficient the community controls, and resort must be had to equitable terms, some using their share by day and others by night. Indeed, the whole principle of water use places the same under community and legal control.

In Lower California:

> Water supply to the cultivated lands is, from mountain streams and also several springs of permanent duration, by law still under the old régime. This country's system of water distribution among planters is regulated through the municipal town council, and is allowed free of taxation, thus being governed by the old rules and regulations of the laws of Spain; the Mexican Government has not yet enacted laws regulating the using of water.

In one of the most important valleys of the Pacific coast, situated in the upper part of the peninsula, 120 miles long by 40 wide, which is entirely without surface water, a valuable discovery has been made of a subterranean stream 70 feet below the surface, which, it is believed, flows through the whole course of the valley.

THE ARGENTINE REPUBLIC.

The Argentine Republic has large areas within its extensive borders irreclaimable without the application of water for irrigation purposes. A system of flooding so that the surplus could readily be withdrawn was in practice before the Spanish and Portuguese occupation; not in Peru, Chili, and Bolivia alone, but on the eastern slope of the Andes, now forming part of Argentina. In his "Conquest of Peru" (Vol. I., pp. 131–133), the historian, Prescott, writing of the soil and its reclaimability by water, states that this—

> was conveyed by means of canals and subterraneous aqueducts executed on a noble scale. They consisted of large slabs of freestone nicely fitted together without cement, and discharged a volume of water sufficient, by means of latent ducts or sluices, to moisten the lands in the lower level, through which they passed. Some of these aqueducts were of great length. One that traversed the district of Condesuyos measured between 400 and 500 miles. They were brought from some lake or natural reservoir in the heart of the mountains, and were fed at intervals by other basins which lay in their route along the slopes of the Sierra. In their descent a passage was sometimes opened through rocks, and this without the aid of iron tools; impracticable mountains were to be turned, rivers and marshes to be crossed; in short, the same obstacles were to be encountered as in the construction of their mighty roads.

These works were largely permitted to go to decay by the conquerors. Indeed so little care has been taken of them that many of their subterranean channels through which water still flows remain unexplored. In other places they still continue to partially fertilize areas where the conduits are broken through. The system of water laws was elaborate, public and communal in character, but under strict general supervision. Overseers under the royal authority were in charge of management, distribution, and repair. Remains of these works still exist in the Argentine provinces of Mendoza, San Juan, and along the upper eastern slope of the Andes. Since the conquest and up to a recent date agriculture has been greatly neglected. The aboriginal population were almost the only cultivators, until late in the present century.

The interior provinces of Mendoza, San Juan, Catamarca, Tucuman, and Cordoba are those in which irrigation is a prime requirement and wherein it is practiced to an extent that gives evidence of continued growth. The average temperatures of these provinces are given in an interesting report by the United States consul at Buenos Ayres. His figures are summarized as follows:

Provinces.	Longitude.	Latitude S.	Elevation above sea level, meters.	Average rainfall in inches.	
				Apr. to Sept.	Oct. to Mar.
	° ′	° ′			
Mendoza	68 49	32 55	2, 623	. 83	3. 47
San Juan	68 35	31 32	1, 131	2. 00	2. 24
Catamarca	60 55	28 28	1, 788	....	....
Tucuman	65 12	26 50	1, 506	2. 05	35. 00
Cordoba	....	....	....	3. 27	10. 04

Mendoza is on an average, San Juan on less than three years, and the other two on two years each.

Provinces.	Mean of temperature in degrees (Centigrade).	
	Apr. to Sept.	Oct. to Mar.
Mendoza (city of)	10. 61	21. 29
San Juan	15. 09	24. 33
Catamarca	15. 44	26. 17
Tucuman	14. 53	21. 19
Cordoba	13. 54	17. 55

The territory of the Argentine Republic extends from 56° to 20°.06 south latitude, so that the variety of climate embraced is as varied as the territorial range is extensive. The rainfall, latitude, and elevation, is given below, as indicating the principal irrigable areas.

These tables illustrate the extreme dryness of the atmosphere, and therefore the need of irrigation. The sources of supply is almost exclusively mountain rivers, streams, and springs, and the trouble with them is their unequal volume. When the snow melts they are full to overflowing, but the waters soon disappear, those in the central system being rapidly imbibed by the sands and possessing no outflow. North and south the streams form part of the Rio de la Plata system, and those south of the province of Buenos Ayres. The distribution is usually of the most primitive character. Dams are built in the streams, and the water is thus diverted at various levels by means of lateral drains, trenches, or ditches with sluices or head gates for admittance to the fields, where checks are used on level ground to facilitate flooding. When the head gates are opened there is no difficulty, as a rule, in evenly filling all laterals, especially in the upper and foothills region. The provinces using irrigation are reported by Consul Baker as follows:

Provinces.	Area in cultivation.	Total area.
	Hectares.	*Hectares.*
Cordoba	234, 395	17, 476, 700
San Luis	19, 809	7, 591, 700
Mendoza	88, 546	16, 081, 300
San Juan	79, 630	9, 750, 500
Catamarca	44, 618	9, 064, 400
Rioja	22, 217	8, 903, 000
Santiago del Estéro	120, 400	10, 235, 500
Tucuman	35, 943	2, 419, 900
Salta	38, 525	12, 826, 600
Jujuy	18, 994	4, 528, 600
Total	703, 077	98, 878, 200

A hectare being 2½ acres (within a small fraction), the total area in cultivation by irrigation will be, in the ten provinces, not less than 1,759,600 acres. The area of cultivation does not exceed 7 per cent of the whole. The chief products are corn, small grains, sugar cane, vegetables, grass, and some fruit. Boring for artesian water has been conducted by the provincial government of Rioja with but little success (1889), however. Catamarca, Rioja, and San Luis are the most arid sections. The best system of works is found in the provinces of Santiago, Rioja, San Juan, Mendoza, and Cordoba, especially the two last named. The figures given by Consul Baker as to the works begun about 1882–'83, by Dr. Juarez Colman, since President of the Republic, show that a number of large dams or dikes, with masonry work, large canals, utilizing different systems, the waters of four important rivers, at an estimated cost when completed of $15,280,000. Their irrigable capacity is put at 3,020,000 acres, or a cost per acre of $27.87.

The control of water, where ditches have been taken out wholly by land-owners, remains in their hands. Where construction has been made by the provincial governments a public tax for use is levied. The private control of water is in the nature of an easement, and can not be separated or sold apart from the land on which it is utilized. The original Inca system of public ownership and direction was broken up by the conquest. But as the great estates then created are in process of breaking up, the land sales are always accompanied by a transfer of water also. The public water tax for irrigation purposes in the two provinces of Mendoza and Cordoba is about $6 per acre (a square is charged $30 and embraces about 5 acres) for one in seven, the tax to be paid quarterly. Water for domestic use is taxed 25 cents per month for each house or family. In Catamarca the price is 6 cents per hour. In Tucuman $3 per mark for twenty-four hours' flow. In Santiago all farms and gardens pay $1.50 per hour for all the water they use, six times or six days in a month. There is a statement in the law of a limit to amount of water to be used.

NICARAGUA, VENEZUELA, AND CUBA.

Irrigation is practiced to some extent in Venezuela very much after the usual fashion of the ranchers and laborers of mixed Indian and Spanish descent. The small streams are the chief source of supply. Coffee requires a good deal of water, as does sugar also, and the great heat of summer rapidly evaporates the flowing water; as a result the crops suffer from drought. There are no important works and no water code or regulations. United States Consul W. S. Bird reports:

> The system of water distribution is governed, according to the best obtainable information, by custom only, although there are some statutes in reference to it that, by common consent, have fallen into disuse. The unwritten law is that each person shall have the right to water on a stated day for a certain length of time, when he must close his flood gate and again await his turn. Under such an arrangement, therefore, it is evident that the amount of water used per acre and per season, and the tenure of ownership, etc., can not be intelligently stated.
>
> Nicaragua uses irrigation only in a very perfunctory way. Mr. H. C. Wills, United States consul manager reports that near Nandaime, a small Indian town in the department of Rivas, three cacao (chocolate) estates are partially flooded in a primitive way by their owners from small rivers or streams being dammed to cause the water to flow over the plantations, which are below the streams.

Some action has been taken in relation to artesian wells, several of which were being bored in 1891, with fair prospects of obtaining good flows. The water is to be used in coffee plantations.

A system of small irrigations exists in Cuba, according to our consul at Santiago de Cuba. There is an abundant water supply, but the summer heat and topographic conditions seriously affect the distribution. The rivers and small streams are numerous enough to fill the soil by percolation and so make natural subirrigation an availing factor. "Los Cantos," a sugar estate on the Bay of Guantanamo, owned by an English firm been have compelled to construct open ditches and irrigate 333⅓ (10 caballerias) acres.

The water supply from the Guantanamo River is dammed above the area irrigated and the water distributed by a system of small ditches. Permission was obtained from the Spanish Government, and the owners pay neither rental nor taxes. The amount of water used per acre depends on the rainfall of the rainy season, and can not be estimated, as the work has just commenced.

IRRIGATION IN EUROPEAN COUNTRIES.

AUSTRIA-HUNGARY.

Consul-General Goldschmidt, at Vienna, reports that in Austria-Hungary, meadow irrigation on a large scale, although generally in an imperfect state of construction, may be found in the southern part of lower Austria; in the Mattig Valley, in upper Austria; near Klagenfurth, in Carinthia; in certain of the upper and central valleys in Tyrol; on the farms of Prince Schwarzenberg, at Wittingau; at the imperial and stud farm at Kladrub; in the Bistritz Valley, and in the Elbe Valley in Bohemia.

The water required is, according to local circumstances, taken either from rivers, creeks, springs, ponds, or other reservoirs. As a rule it is conducted from rivers or creeks with its natural head into channels or ditches. The water course is generally stemmed, more or less high, at the place where the conduit is to be started, by a suitable dam, which will cause the water to flow into the irrigation channel. The latter is at its source or beginning generally provided with a gate, which serves to protect it from floods and to permit of its being laid dry when required.

For small meadows there are in many places found wheels for raising the water from the natural watercourse (creek or river) to the higher border land. Those wheels are equipped with buckets, which are hung in and are moved by the currents of the streams in which they are suspended. They are found in large numbers on the Eisack River, in Tyrol, above Bozen. For irrigating extensive meadows at Kladrub, in Bohemia, for instance, a 30-centimeter centrifugal pump is put to work when the Opatovic Canal contains too little or no water. This pump is then operated by a 12-horse-power portable engine, and raises the water from the Elbe River to a height of 5.5 meters.

Wells, tanks, or cisterns are generally employed for the irrigation of kitchen gardens only. Arrangements of this kind may be found in the environs of large cities, especially around Vienna. In this kind of irrigation the water is, as a rule, pumped from the well, tank, or cistern by means of horse power.

In localities where but small supplies are found in creeks or springs, basins or ponds are formed by the erection of suitable dams.

Such small basins or ponds have been constructed, for instance, at the trifling cost of 100 florins at Guttaring, in Carinthia, for the irrigation of a large meadow of 3 hectares, and on the Saager farm, in Carinthia, for a meadow of 1.7 hectares, when the total cost of construction amounted to only 85 florins.

Consul-general Goldschmidt says, that:

In Austria there exist no special institutions for the supply and distribution of water from the main conduits (canals, etc.) for irrigation purposes, as, for instance, the so-called "water module" in upper Italy. Such arrangements are not known in Austria, for the reason that here no independent enterprise exists for vending quantities of water from canals. The distribution of the water into the different side ditches is effected by simple, mostly wooden, gates, which are raised or lowered according to requirement.

There is no general code in relation to the use of water, and when impounded it is regarded as private property. Provincial laws exist for the control of water corporations, which provide, among other uses, that of irrigation and drainage. The corporations have a municipal or district character, and the propriety and need of inaugurating either irrigation or drainage enterprises is to be decided by votes that represent the preponderance of acres in the area to be affected. Another law passed in Austria June 30, 1884, provides subventions from the states and provinces to the extent of 60 per cent of the total cost of irrigation and drainage constructions. In the Goriz district irrigation for rice is practiced. Irrigation for grain fields is now planned in connection with the Marchfield plains, near Vienna. In the mountainous portions of the Tyrol meadow irrigation is both ancient and extensive. Many old irrigation works have been reconstructed and improved, and new ones have been constructed in great numbers.

Several of the Bohemian canals constructed for power and navigation are also used for both drainage and irrigation. The same thing is true in Austria.

BELGIUM.

Irrigation is practiced in Belgium, chiefly for the cultivation of meadow lands. There are numerous small works and canals for that purpose. There are 16 navigable canal systems with a total length of 587,773 meters (367.3 miles], the water of which is often used in agricultural processes, as, for example, in the flooding and draining of the flax pits in aid of the process of "*rouissage*," or decomposition by "retting" or "steeping" in water. These canals are all the property and under the control of either state, province, or commune.

A net work of canals known as "de la campine" are the chief artificial channels used for the irrigation of meadow and moorland. Considerable use is also made of the rivers Scheldt and Meuse, and their affluents. The canals named have a length of about 350 miles, and were constructed for both navigation and irrigation purposes, at a cost of $5,000,000. There is considerable and successful enterprise in the way of reclaiming moorland by means of irrigation. The profit already obtained is about $22 per hectare (nearly 3 acres). Consul J. A. Stewart, of Antwerp, says:

> No tax of any kind is collected for the use of the water of the canals for irrigating purposes, and no engagement of any kind exists between the parties interested, *i. e.*, the state and the proprietors of the land under irrigation. Such proprietors have a uniform right to the water available from the canals, the requirements of navigation having been previously satisfied. Permission to establish trenches from the canals for irrigation are generally granted under certain conditions. They have to be constructed according to plans sent in with the application, and approved by the Government. The applicant will be held to keep the land irrigated under cultivation, and not use it for any other purpose.

DENMARK.

Irrigation for reclaiming heath land is carried on in Jutland, Denmark, by a corporation organized for that purpose. About 90 square miles or 55,000 acres, out of 140 square miles or 71,600 acres, have been brought under use, 6,400 acres as plantations and the balance as meadows and fields. The work done is divided into: "(1) Construction of irrigation canals; (2) plantations in general; (3) limited plantations on the different properties and inclosures with quickset hedges; (4) draining of bog lands; (5) cultivation of marsh lands."

There are 145 canals in operation (1890), carrying 22,000 second-feet of water and having a varying length of from 5 to 15 miles. The 21,000 acres of land under cultivation have increased in value $1,600,000, or nearly $80 per acre. The total cost is estimated at from $80 to $270 per second-foot, or a total of not less than $300,000, and administration is arranged by each canal. One crop is made per year, a local board is chosen, and they divide the water each season; that is, from April to December. Conveyance to meadows is made in wooden troughs.

In all there are 51,400 acres of forest plantations. The corporation controls and owns 6,300 acres for experimental planting. Its work forms a very interesting reclamation exhibit.

FRANCE.

According to the report of Consul-General Rathbone (1891), the total area irrigated in France is 7,000,000 acres. All irrigating canals are river-fed. Reservoirs are few in number. The works consist, first:

Of a principal canal, or chief branch, through which the volume of water to be distributed flows from the river; second, of a smaller canal, fed by the principal one; third, of a network of streams, drains, and ditches, which provide each landowner with the quantity of water to which he is entitled.

The use of water for irrigating is regulated by the French code. The articles bearing particularly on this point are as follows:

643. The owner of the spring can not change its course when he provides the inhabitants of a commune, village, or hamlet with the water necessary for them, but when the inhabitants have not acquired or prescribed the use of the same the owner may demand a compensation, the exact amount of which is to be fixed by an expert.

644. The owner of a property skirted by a running water which is not national property, according to article 538, has a right to the use of the water for irrigating his lands while it flows past them. The owner of ancestral lands traversed by this water may use it within the full limits of his lands on condition he restores it to its proper bed before it leaves his estate.

645. If a dispute arises between the landowners to whom this water may be useful, the tribunal called upon to give its decision in the matter shall conciliate the interests of agriculture with the respect due to the rights of property, and in every case with the particular and local customs and regulations which pertain to the passage and use of water.*

Recent enactments provide for some additional rules, the text of which is not at hand. Springs are owned by persons, by the state, or by the communities. Running waters are regulated, as to use, by law. Navigable waters belong to the state. Irrigation works are executed either by syndical bodies or by contractors working for public bodies. A hectare is very nearly three English acres, and the cost of water on several of the leading canals is given per year at from 35 to 80 francs per hectare, or from $2.33 to $5.33 per acre. Consul-General Rathbone states that:

The cutting of a certain number of canals for irrigation in the southern districts dates back several centuries. The more important works, however, are of comparatively recent origin. During the last ten years, especially, a great impulse has been given to the construction of works devoted to irrigation. Subjoined is a list of the most notable enterprises of this kind. It is taken from the "Journal d'agriculture pratique."

Departments.	Description of works.	Cost.
		Francs.
Drôme	Canal de la Bourne	13,000,000
Alpes Maritimes	Canal de la Vésubie	7,000,000
Aude and Hérault	Canal to be used for submerging both departments.	2,400,000
Drôme and Vaucluse	Canal de Pierrelatte	8,000,000
Basses-Alpes	Canal de Manosque	4,500,000
Hautes-Alpes	Canal de Ventavon	2,000,000
Aude	Canal de Canet	1,000,000
Bouches-du-Rhône	Drying up the Fos marshes, and purifying the waters of the Crau.	18,000,000
Herault	Canal de Gignac	4,200,000
Loire	Canal de Forez	7,000,000
Alpes-Maritimes	Canal de Foulon	1,200,000
Aude	Canal de Cuxac	2,000,000
Do	Canal de Luc	1,160,000
Do	Canal de Fabrezan	
Total		41,460,000

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*Consular Report on Canals and Irrigation, 1891, p. 99.

> The public treasury generally contributes one-third of the cost of the works; the land owners interested in them defray the remaining two-thirds. In the case of the most important works, the State, besides contributing its third, has guarantied for the space of fifty years to the parties who covered the loan raised for the purpose of carrying out the works the interest due on the sums lent to the contractor.

The department of des Bouches-du-Rhône borders on the Mediterranean to the east and comprises the territory surrounding the mouth of the river. The chief source of supply is the Dorrance River, a mountain stream of considerable volume. Its floods have often been destructive in character. The area of irrigated land has largely increased during the past thirty years. The water surface (artificial) devoted to irrigation purposes was given some years since at 1,378 acres, while that of the natural lagoons, rivers, lakes, and streams is stated at 134,500 acres. The cultivated area was given twenty years since at 876,000 acres. It is now about one million. The products of this department include olive orchards, vineyards, and other semitropical fruits and products. The cultivation of wheat is also increasing. The small farming of France reaches it best development in the south of France. United States Consul Trail, of Marseilles, says:

> Properties of this sort are frequently not more than 20 acres, sometimes much less, that being all the land one average family can cultivate without the employment of hired labor. The products of such a farm are raised on small patches. One frequently sees but 1 acre given to wheat, another to the vine or olive, several for gardening, and the remainder in pasture on a 10 or 15-acre farm. This diversity of production prevents the farm work from being overexacting at any one period, enabling the family to work on the different crops at different times, and keeping it busy all the year round. Besides, it is found, even on these small farms, that marked differences in the soil occur, so that experience has taught that it is more profitable to divide up 10 acres in several cultures than to confine them to but one. These small farms require little or no machinery in the American sense of the word.

Irrigation in this department is as ancient as the Roman occupation of Gaul. At that early day canals were dug to conduct the water of the Durance to Arles and Salon in the southward. All subsequent authority has encouraged these irrigation efforts, however rude they may have been. Syndicates have been formed to construct roads, against the sea and the river and floods, to drain lagoons, to irrigate the land. For drainage purposes there were in 1890 fifty-three of these syndicates, and for irrigation eighty-one. There are two classes, one under Government control, and the other elected by those interested. Each syndicate represents one work, which makes eighty-one, the number of canals, the largest of which are the Crapponne, the Alpines, and the Marseilles, for all of which the Durance is the source of supply. The first-named system was constructed in the sixteenth century. It irrigates about 30,000 acres. The canal supplies the city as well as the land under its course by a system of ditches, conduits, and pipes exceeding 100 miles in length. The annual receipts are about $300,000, and the cost of water for irrigation is from 27 to 190 francs annually, or from $5.40 to $38 per year. Water is sold by the measure, not by the acre. Consul Trail says:

> The French law permits a farmer to use all the water necessary to irrigate his fields from a river flowing through or by his land free of cost. When the land is lower than the river surface the question of embankment may be the most important for that particular property; when above the level, the cost of pumping the water up to a desired point for immediate distribution or for storage in a reservoir takes a most important place in the items of yearly expenditure for that estate, so that the value of rural property is governed by the ease and cheapness with which water can be obtained, or the contrary. Where nature alone has to be relied on for the rainfall the value of land, as given before, is very low, as the only products under that condition are a coarse and scanty grass and a few trees of little or no value.

In answer to the question sent in 1889 by the Senate Committe on Irrigation and Reclamation of Arid Lands, through the State Department, the various United States commercial agents in the Marseilles consular district state that there is under irrigation in nine communes a total of 93,762 acres. These questions, prepared by the writer as the committee's expert, were as follows:

(1) Areas of land under irrigation; compare with the nonirrigable and cultivable areas when possible. Also, quantity and quality of crops grown.

(2) Sources of water supply, whether from rivers, streams, springs, lakes, wells, reservoirs, catchment basins, or tanks, etc.

(3) Character of works used for storage and distribution of water.

(4) The system of water distribution, whether governed by laws, rules, and regulations, or custom. Give duty of water per hectare, *i. e.*, the amount used per hectare and per season; the cost or rental to user; tenure of ownership of water, and whether the same be public or private, national or community.

(5) Character of climate in irrigated region and nature of soil; annual rainfall or other precipitation.

(6) Antiquity or otherwise of irrigation systems within the section treated of, and whether the same are maintained at public or private expense.

There are private ditches, and some controlled by riparian rights, but the larger number are the property of the communes themselves.

The United States consul at Rouen, Mr. Williams, writes of the river and canal revenue and funds, as follows, so far as the subject in the north of France refers to irrigation and forestry:

> The rivers serve other purposes, such as reservoirs for man and beast and domestic purposes, and irrigation of the streets of villages and cities and irrigation of land. For the last-named purpose this district has no use. A considerable source of revenue arises from the sale of forests planted on lands redeemed by dikes, and the banks of canals upon which trees—principally willows and poplars—are grown, which sell on an average at 20 francs apiece at the growth of thirty years.
>
> The revenue from this source alone was 345,053 francs in 1887. The wood sales of the navigable waters of the department of the North and Pas de Calais were, from 1883 to 1887, 69,500 francs, and will be much more when the growing groves will be matured. The net profit of the sale of 18,000 poplars on the Seine was 414,000 francs in forty years, or 10,350 francs per annum. The trees add not only to the beauty but to the comfort of these waterways.
>
> The falls are utilized as a motive power, and they become vast reservoirs where fish are extensively propagated. They sometimes break through their banks and do much damage to lands, and become the depositories of much unhealthy matter and require great outlay for repairs.
>
> The importance of the waterways of France is conceded on all sides, and their extension and amelioration have received the careful consideration of every administration, and of none more than the present.—(Canal and Irrigation, Consular Report, 1891, p. 119).

The Forez Canal, in the Department of Loire, and supplied by the river of that name, irrigated 65,000 acres. It was begun in 1863, and the National Government has granted for its construction $122,200, and loaned the balance needed to the department at 4 per cent. In 1886, date of latest report, there were 23,000 acres served, with a length in ditches of 115 miles, at a cost of $219,104, or nearly $9.50 per acre. At that rate a total cost of the system will not be less than $598,000. The water is sold by volume under gauge. The distribution is in general periodic and collective, through pipes carrying the water to a point most convenient for a group of farms. From the pipes head or flood gauge the water flows into farm laterals. This service is always once a week, on the same days or hours, the amount received being regulated by the amount purchased. The delivery commences on land furthest from main canal. Each proprietor turns off the water from his lateral when he has received what has been paid for, and the next in order is served. The system works well. The assessment tables are made out by November 1, and notice is served on each irrigator of the days and hours when water was applied to each parcel or piece of his land. The smallest proprietor is served at least two hours, and the amount ranges from 7 to 15 liters per second. This irrigation is almost wholly employed on meadows. The methods are small ditches on slight grades or by wooden troughs where the land is flat. The results obtained are stated to be profitable and satisfactory. Land has increased in value from about $44 up to $300 per acre.

The Department of Lozére is the most elevated in France. Irrigation is practiced there quite extensively, but in a primitive fashion. The fields are flooded by cutting the stream banks. All springs are collected through pipes and delivered to the land. The people of this department make their own water regulations. Riparian rights, regulated by needs, are recognized. The water must be restored to its natural course after use and be received by those below. Passage over other lands is permitted on indemnity for all works necessary to convey water. Courts have summary jurisdiction, and the prefects may make police regulations, if required.

ITALY.

Irrigation in Italy was probably as ancient as the rule of the Etruscan people. It certainly was an early and important part of Roman economics. It has had a distinct purpose in the agronomic life of the peninsula ever since. But its present importance dates from the works inaugurated by that almost universal genius, Leonardi di Vinci. At the present date the principal seat of cultivation by irrigation is in Piedmont and Lombardy. In 1878 there were the following areas under cultivation by irrigation:

	Acres.
Lombardy	2,034,000
Piedmont	1,329,000
Venetia	122,000
Emilia	288,000
Other provinces	642,090
	4,415,000

There are nine principal canals in Lombardy which are navigable as well as used for an irrigation supply; the mileage of the system is extensive. The Piedmont main canals are 253 in number, with a length of 1,207½ miles. Venetia has 203 navigable and 40 minor canals. The latter are chiefly used in irrigation. It is estimated that about 500,000 additional acres can be brought by these means under intensive cultivation. In the last twelve years there is no doubt that the increased acreage under irrigation will make the total at least 4,600,000 acres. In the Progress Report for 1890 of this office the local laws and regulations are given.

United States Consul Edward Camphausen, at Naples, writes:

> There are some lands under private irrigation. The water supply belonging to the respective landowners is taken from wells at a depth varying from 25 to 100 feet, water being found in abundance at that depth in most parts of the country. Near the coasts of the Adriatic and Mediterranean wells are formed by the infiltration of saltwater. Some of these belong to communities, but no definite law or regulations appear to exist for the use or distribution of the water, and there is no irrigated land in the true sense of the word in this district.

The Italian Government has expended large sums of money since 1865 on irrigation works, and in 1883 it was empowered to loan funds (principal payable in thirty years) at 5 per cent to "irrigation associations" (consorzi) and to provinces and communes for the purpose of carrying on works of irrigation; provided the supply of water to be obtained shall be not less than 25 gallons per second, and provided the province or commune advances an amount at least equal to one-tenth of the sum loaned by the State.

In Sicily especially, and throughout southern Italy, all fruit culture is carried on by irrigation, which is in all instances required throughout the summer months, the proportion of nonirrigated to irrigated groves in extent being as 1 to 15. One hundred 10-year old lemon trees that are watered produce on an average 15,000 lemons; whereas 100 trees that receive no water (other conditions being equal) produce but 10,000, or one-third less. The groves are watered from twelve to twenty-five times during the summer; that is either once every two weeks or once a week. At the last spring working of the trees the land is trenched, in order to obtain an equal distribution of the water. Parallel trenches are opened (generally about 6 inches deep and 8 inches wide at the bottom) between the rows of trees, the intermediate space being divided into symmetrical squares or divisions.

Prior to 1866 the water for irrigation was owned by private individuals, the municipality, and convents, or religious corporations. In that year, however, the Government confiscated all the property of the latter to which there was a clear title or in which no outsider, public or private individual, had an interest, so that now it controls all the water formerly owned by the religious bodies in question, which by far exceeded that owned by the municipality and private persons combined. This water the Government either sells or rents.

According to the reports of our consul at Messina, the—

> Distributing of water for irrigation purposes when the water is private property (for by law the owner is allowed to make what use of it he pleases provided he does no damage to his neighbors) is not governed by law, but by special customs that vary with the locality, and which it would be impossible to enumerate. The cost of water for irrigation purposes is so complicated a matter that it can not be fixed precisely, but this much can be said: In this province a penna (a goose quill) of water, *i. e.*, 36 gallons of water, per hour costs from $200 to $260 per annum.
>
> Here, as a rule, water, is private property. Some communes own water, either by purchase from private parties or because its source is on community land.
>
> The title to water is acquired by bargain and sale, exchange, gift, and can also be acquired by prescription. Not less than thirty years of undisturbed enjoyment are necessary to create title by prescription.

Irrigation is commenced on April 15 and terminates September 15, annually. For obvious reasons it is not resorted to during the winter, excepting for promoting the development of grass lands.

SPAIN.

The total area of irrigation in Spain is variously estimated at from 700,000 to 6,000,000 acres, the latter being the estimate given by United States Consul Perez, at Santander, of the area benefited by irrigation. The first-named estimate embraces the cereal, vegetable, and fruit area; the latter that of the forage plants and grass lands. The total cultivated for crops and pastures in the kingdom is given by the same authority at 120,000,000 acres. One of the most notable plans for irrigation is that applied to the cultivation of meadows in the northern coast provinces and known as the "spike channels." Mr. Perez says:

> The system for irrigation of meadow lands most commonly applied in these provinces is that denominated "irrigation by inclined channels," or also "spike channels" ("riego por requeras inclinadas" or "requeras en espiga"). The distribution channels are devised nearly in the sense of the greatest slopeness of the grounds; the irrigation channels connect with them and spread out to right and left. A rapid

sectional change takes place in the distribution channels at the point where they separate into branches with the irrigating channels. The last-mentioned channels, by having a gradually narrowing section from their parting point down to the opposite end, pour out the water by getting inundated. Another contrivance is also combined with this briefly described distributive system, which consists of collecting channels, called "azarbes," dug on the natural lines of junction on the meadow ground, terminating in an outlet channel. Sometimes, when the extent of the meadow is not considerable, or when the quantity of water available is but small, the collecting channels are changed into new feeding channels for the supply of other lots situated farther down.

Any reasonable attempt to illustrate the irrigation works and methods of distribution would require a volume in place of the few pages at the writer's command. It will suffice to say that irrigation in Spain goes as far back as Iberian life, existed under the Roman conquerors, was systematized and localized by the Moors when they controlled southern Spain, and that it has within the current century taken a new lease of life and enterprise. Engineers study the works of Spain for their construction merits; and as among the applications of hydraulic principles, legislators find in the codes and laws adopted by the national government as well as in the rules, regulations, and customs by which provincial local and municipal control is maintained over the natural wealth-water, a constant series of models for application elsewhere and under almost all varieties of circumstances. Agronomic economists are guided at every step by Spanish experience in learning and estimating economy in the use of water, the value of land and products under irrigation, and the means and methods by which such results are achieved. The former Spanish control of large areas of our own territory has left marked influences upon the conditions under which irrigations must be operated. The study, therefore, of Spanish irrigation results, laws, regulations, customs, and of the constructions in use, will prove of value to all who desire to understand the legislative and economic, as well as engineering needs of an arid or sub-arid country, whose agriculture must be largely carried on by means of irrigation.

IRRIGATION IN BRITISH DEPENDENCIES AND COLONIES.

IN BRITISH COLUMBIA.

The southern and central portions of this section of British America has most of the characteristics of eastern Washington, and requires, as it does, irrigation for security of crops. The climate is dry, the rainfall quite small. The interior is a great basin, broken by small ranges and hills not much elevated, and is drained by the Frazer and Thompson rivers, and lakes. There is a marked absence of forest trees and the river basins and valleys are of great size. Irrigation is practiced to a moderate extent at several points, notably at Ashcroft, where irrigation is used in general agriculture and fruit growing. There are a number of ditch enterprises; one, known as the Boston, being 14 miles in length, and costing for construction $60,000, $4,285.71 per mile; somewhat less than $5 per acre. This ditch failed from want of good engineering and cost too much. At Hat Creek, near Ashcroft, there is an enterprise drawing water from a small lake and costing about $5,000. From the eastern slope of the Cascade range to the western one of the Selkirk Mountain, or as far east as the one hundredth meridian of west longitude, the storage and conservation of water for irrigation will become a necessity whenever farming begins on an extensive scale.

Mr. C. F. Cornwall, a prominent citizen of British Columbia, writes to United States Consul Stevens that there are a number of irrigation enterprises and that without it—

> The cultivation of the soil in such portions would be fruitless; with it the most satisfactory results are attainable and attained. * * * Though irrigation of land undoubtedly adds a certain percentage to the expense of cultivation, yet I think it can be indisputably proved that the advantages resulting from its use amply repay the increased cost. The average yield of crops under well-applied irrigation is very large; far larger than in unirrigated districts, however fruitful they may be. The use of the water, doubtless to a certain extent, enriches the land, and so rapid is growth under its beneficent stimulating effects, that in these comparatively northern latitudes produce is brought to a perfection of species which you would only expect to find flourishing in more southerly climes; for instance, besides all the usual grains and roots common to temperate climes, in these districts, under irrigation, flourish fruits of all descriptions—grapes, melons, cucumbers, tomatoes, maize, apples, pears, plums, etc., all too numerous to mention—and attain a maturity and perfection which is astonishing. Such would not be the case were such latitudes subject to the cold which is associated with a degree of rainfall which would render irrigation unnecessary. I think that most farmers who have experienced practically the advantages of irrigation would be unwilling to pursue their avocation in districts where its use was unnecessary or impossible.

Legislation in this province, adopted in 1873, making provision for ditching and diking, goes into administrative details with great care so as to retain control in the hands of the authorities. The act provides for the appointment of district commissioners, specifies their powers, and directs them how to carry on the work,—for cases in which the land is partially owned by the crown; for overseers; how to give notice to proprietors; how and for what, assessments, fines, and rates are to be made;

provides that lands may be leased or sold for payment of rates; that the land is liable only where the owner has not agreed to the works or for actions by owners against commissioners; that owners and occupiers shall furnish labor; fine may be levied for neglect of assessment of damages to sods or soil; that record is to be kept by clerk; the fees for inspection and extracts; as to cases of salt marshes and necessary breakwaters; assessment may be made only upon land benefited. Clerks are to be competent witnesses; commissioner must not be a clerk; how plans may be obtained; as to outer dikes and inner dikes; how kept, outer dike ceasing to protect inner; proprietors of inner dikes have recourse to compel repairs of outer dikes; injured dikes, how repaired; mode of making application for drainage—duty of commissioner; mode of valuing and assessing damage to lands—cases of two proprietors, but neither owning two-thirds, how provided for; occupant may appeal to Supreme Court; fine for official neglect; verbal notices valid unless otherwise specified; commissioners not liable for acts of predecessor; lieutenant-governor in council may in certain cases guarantee interest on two-thirds money for diking; assessments for the interest so guarantied, lien on the land therefor.

BRITISH AND NATIVE (DEPENDENT) STATES OF INDIA.

The peninsular region of India embraces irrigation, engineering, and economic problems of the first magnitude. Topographically speaking it is an area remarkably self-contained. As related economically and socially it is self-developed. In climatology, though it largely lies under the equator or is close thereto, it has many distinct types, and ranges from the lowest to the highest degrees of humidity and precipitation, of heat and cold. In population the region is one of the largest; in racial and ethical associations it possesses many and varied conditions. To the agriculturist and economist interested in irrigation questions, it presents peculiar attractions. In formation India is an equilateral triangle, whose apex is the "roof of the world"—the vast central Sierra of Asia. The distinctly arid portion embraces the Himalayan Range and projects southward, like a huge diamond in shape, into the elevated central plateau of the peninsula. The shore portions, made from river deposits and practically their several deltas, are somewhat in the shape, on either side, of elongated triangles whose lower points meet in the Indian Ocean. The western triangle is the wheat region; the east the rice growing. At the south are the cane fields and other tropical products. In the arid section or plateau region the cereals, millet, maize, barley, sesame, etc., are grown. There are many important streams and several of the world's great rivers. They are both snow and rain fed in character, the latter being the largest and most important. The Indus, Ganges, and Brahmapootra are all larger than the Nile, the latter being four times as great in volume. The population of India follows rainfall, and evaporation producing aridity, renders the crowded life precarious. The soil of India is almost everywhere saturated with moisture. Mr. Deakin says: "By far the largest section of all is watered by wells," and their contents are lifted by means of "hand or bullock draft." Except at the head of the sub-mountain plains, where the supply lies too deep for present use in an economical manner, "there is water under the soil almost everywhere." Even in the sub-Himalayan provinces, "the plains are honeycombed with thousands of wells stretching southward."

The Crown is the general landowner. Legally speaking, it is the only landlord. All waste and unoccupied lands are distinctly controlled by the imperial administration. Their use adds to the common wealth and gives security to the empire. Irrigation offers the way for use. Since the Indian authorities have perceived the relations of land and water, as vested in a representative source and an administrative authority, learning the lesson left by the seven famines of the last half century, they have been sedulously endeavoring to re-create older Indian forces and habits with modern capacity and capital, to make safe the tiller of the soil, and to insure them against famine and its horrors. There are nearly 131,232,180 acres under cultivation, less than one-fourth of which are under irrigation works. There are 80,000,000 more, according to Prof. Wallace, that can be reclaimed. There have been large additions in this generation to the cultivatable area in Madras, the northwest provinces, Bengal, Sind, and the Punjab, while gaunt famine is slowly but surely passing away. The farm villages have increased by many thousands and the land or rent revenues have grown in proportion. The policy of loaning for public works, especially those of irrigation, has had much to do with this progress. It has become so settled a course of action that 75 per cent in value of all land that can be irrigated, and so improved, may be borrowed of the imperial administration. It is worth while to inquire into these facts, which among others have made of the Indian ryots, in wheat exports, the most formidable of competitors to American farmers.

There are two seasons or harvests per year over the larger portion of India, known as the "kharif," or summer, and the "rabi," or winter season. The "kharif" is the season of greatest rainfall, and in the low lands, the northwest provinces, Bombay, the Punjab, and Central India, the precipitation is reckoned per season at from 20 to 40 inches. In "rabi" the rainfall ranges from 2 to 10 inches per season. The southern central portion and Sind may be compared with Arizona, southern Utah, and the San Joaquin Valley, California. This twin irrigation often doubles the crop capacity. The government control of irrigation works and administration is practically absolute outside the native states, and within them the idea of common or public property, strictly prevails. It disposes for use of all water, controls and manages the same, and it directs the distribution thereof. Water rates are assessed on irrigated areas, and these vary according to crops raised; so also does the amount of water required, some crops being more thirsty than others. Community ditches and works are constructed and conducted under official supervision by the villagers themselves. Canal officers measure and oversee the supply. There are presidency departments of land, revenue, and water supply; also of public works, and a general department at Calcutta for the whole empire. Engineers in chief, superintending executive, and assistants—are appointed. They all have magisterial powers in the line of their duties. There are native deputies, magistrates, constables, and overseers. The chief engineer in each presidency or province is in authority, subject to the Indian council at Calcutta and the secretary of state for India at London. The Indian canal works are divided into "perennial," supplied by and subject to regular seasonal fall; the "inundation," subject to torrential filling and sources; storage and drainage works. There are also the native wells and tanks, all of which are carefully encouraged and looked after by the government. The one division may be termed general and the other local. The inundation canals are found chiefly in the great valley of the Indus, and their main feature is the absence of permanent head works. This is in striking contrast to the suggestion made in the United

States by one class of theorists in irrigation matters, that the use or storage of storm, torrential, or inundation waters must be accompanied by the creation of costly works, to be placed as a rule at high altitudes and under topographical conditions that are likely to insure the rapid washing away and destruction of dams and embankments as well as the silting up of channels. Possibly a solution of the more important problems involved may be seen in the utilization, as under the Maxwell system upon the Raton table lands in northeastern New Mexico, of great natural depressions on the open plateau as storage reservoirs. In this case, the mountain supplies are drawn direct from the cañon streams and conveyed by large artificial channels to the old lake beds or great playas which abound in the table lands. From these the distribution is easy. But, returning to Indian works, we find that for inundation canals the supply stream must generally flow at a relatively high level to the section to be watered. The channel bed should follow a ridge; in other words, be a "high line" canal. Sometimes the water is thus conveyed over lands by channels that are higher than the fields. Other canals of this class must be constructed with rivers subject to long annual overflows. A thorough system of drainage is a necessary part of such works, as otherwise there is seen the "reh," or rising alkali, the undue rise of the sub-surface water level, the creation of marshes, accompanied by epidemics of chills and fevers. The perennial canals are an accompaniment of the mountain-fed streams and supplies, such as the Jumna, Ganges, Sutlej, and others. Many of these streams will rise during one season from 5,000 to 300,000 and even 1,000,000 second-feet. Mr. F. A. Franklin, C. E., of the New South Wales water supply department, in a report on certain aspects of Indian irrigation, gives in one paragraph so clear and simple a description of the same that it will bear quoting. It is as follows:

> The main channels in every case are formed on the ridges to be found on each side of the main rivers. These ridges, which exist in varying widths, right and left of the river channels, have been formed by the gradual deposit of alluvial matter when the rivers have been in a state of flood, and they occur at points where the velocity of the stream is checked. The effect is to leave on each bank a stratum of silt, in the sectional form of a long wedge, with the thick end towards the river. The width of this slope on the plains of India varies from 300 yards to a distance of many miles. Beyond these deposits, which occur also on all tributaries of such rivers, the country is low, and although not perceptible to the eye, yet instrumental examination shows in which direction the drainage tends to flow. The irrigation of India is therefore based on a very simple principle.

Madras, with a population of over 31,000,000, and the great alluvial delta made by the mouths of the Godaveri, Kistna, Penner, Kaveri, and Tramprapani, contains a number of the largest and most useful irrigation works. They are divided into "productive," "protective," "minor," and "navigable." The first are works constructed from government loans and charged with interest; the second are works designed for protection against famine. The others are local works, or those connected with navigation, but incidentally only in aid of irrigation. The investments up to the year 1890 are as follows:

Productive works	$25,840,000
Protective works	768,000
Minor and navigation	5,880,000
Total investment	32,488,000

The pound is estimated at $4.80. This is slightly below exchange, but affords the most convenient unit of computation, and is sufficiently accurate.

The acreage watered is given for 1889–'90 at 6,000,000. Of this total 2,300,000 acres are under the major works. In addition to a very large increase of land revenue, the revenue from water supply was $8,400,000. The deficit in interest on loans was $1,726,160, deducting which the net return for the fiscal year 1889–'90 was $673,840. This is in addition to $480,000 remitted to land owners. State irrigation in Madras is, therefore, a direct and brilliant pecuniary success. Before the Anglo-Indian administration assumed control there were only 750,000 acres irrigated, mostly from wells and village tanks. A direct addition of 5,250,000 acres has been added to the area irrigated, and the revenue has swollen from $432,000 per year to $2,400,000. The present value of irrigated crops is stated at $79,200,000. In fact, the Government investment pays from 30 to 45 per cent per annum. The native people are well off. Of the land seven-eighths is controlled by those who work it. There are 35,000 villages, each with less than 500 inhabitants.

> The ryots have become [says Mr. Deakin] by tradition and practice experts in the art of irrigation, though their greediness and selfishness often lead them to apply too great a volume of water. Unless they are watched they will at any time of need turn drainage cuts into irrigation channels by damming them, to the injury of their neighbors and of the system. There is no feeling of obligation on their part to the State or its officers, but, on the contrary, any attempts to improve the alignment of works are met at once by exorbitant demands for compensation. The harvest which irrigation has brought them is thus often used to fight the Government, which has given them the means of irrigation.

The great Madras works were originally planned as huge private enterprises, but their failure as such was so conspicuous, that the presidency authorities were compelled to buy them all in at a cost of $10,367,260. Free water was granted for five years, from 1882 to 1887. At present, until 1892 only one-half the water rate has to be paid. The nominal cost is 24 cents per acre; the actual cost is 12 cents. Perpetual maintenance is provided for on a total payment of 48 cents per acre. But the primitive native system still largely prevails. The number of wells used for irrigation is not returned, but it is not less than 30,000, and the area they serve is at least 3,000,000 acres. There are 60,000 village tanks or reservoirs, whose embankments of 6 feet in height, says Mr. Deakin, would if stretched out make a girdle 1½ times the circumference of the earth. The Australian statesman says:

> We find first and most often the well. There are wells in the north, center, along the eastern strip, and in all river or other basins; river-fed canals in the north and northwest; deltaic canals in Sind, Bengal, and Madras, and reservoirs in the interior plateau, on the west coast sometimes feeding canals, and on the east often dependent solely upon rainfall. The natural conformation of the country has been studied and followed by its inhabitants. Wherever there has been water available it has been eagerly seized upon. Whether by well, by reservoir, or by canal, it has been caught and utilized. Wet cultivation is being carried on in all quarters and in all conditions. In a word, where the rainfall is deficient, India is irrigated in every part where irrigation is possible.

Outside Madras, private companies for irrigation construction, supply, and management have had no special trial, and in that presidency they have been failures. Bengal, a land almost built up by river silt, for the Ganges alone in a course of 1,200 miles has created a delta 300 miles in width, and lying, too, under an equatorial sun, has a modern public irrigation plant costing some $28,800,000, serving in 1889–'90 in all some 2,500,000 acres. When the works began in 1870 there were 900,000 acres irrigated in the presidency of Bengal. This included the small as well as large areas. The chief product is rice. The canals now in use, begun as private works, were bought out and finished by the Government some ten years later. The system has several times demonstrated its capacity to save the native people from the consequences of crop failure. More than that, the insight gained into native affairs and mismanagement by Anglo-Indian officials of the cold, logical type that engineering capacity and experience must produce, has led to the correction of great abuses, such for example as that of rack renting the ryots, under which within fifty years the Zemindars raised the rents from 140 to 290 per cent.

In 1885, in Lower Bengal there were 475,000 acres; in 1889–'90 there were 560,000 acres under cultivation by irrigation. This increase represents about the average increase of such culture throughout India. In the Sone circle the system of works connected with the Ganges and Sone rivers are of an important character. Originally 800,000 acres were brought under them at a cost of $18,120,000. There were in 1890 1,305,000 acres of rice land served, with a total area of 2,611,000 under ditch. The Ganges system of canals is among the greatest in India. That of the Upper Ganges embraces 890 miles of principal channels, 3,700 of distributaries, 282 of outlet channels, 31 locks, 202 bridges and navigable sideways, with 17 great dams. The system was projected in 1842 and completed in 1884. It serves 1,205,000 acres, and has cost $14,644,000. The Lower Ganges system embraces 531 miles of main canal, 1,854 of distributaries, 428 of navigable channels, and 56 of escape or overflow cuts. About 620,000 acres are served by this system. The cost has been not less than $7,000,000.

Bombay in 1889–'90 had 839,000 acres irrigated, and the public canals commanded 915,000 acres. Altogether there were 24,500,000 acres under cultivation in the presidency of Bombay. The irrigated crops in the last-named year were valued at $1,867,200. The expenditures of the "protective" canals has been $2,454,400; on the major or "productive" works, $8,337,600 have been expended, making a total cost of $10,792,000. Mr. Deakin writes of Bombay that—

> A summary of the results of irrigation in Bombay is not to be derived from any merely arithmetical standpoint. The Government is satisfied with the progress made, and the Department is sanguine of yet presenting good balance sheets. Security has certainly been established over large provinces against the suffering, loss, and death which follow in the train of famine. But the changes flowing from it do not depend only upon such contingencies, nor are they remote and anticipatory only. In the old days of Maratha warfare neither life nor property were safe outside village walls, and consequently the trembling ryots herded together in little fortified places for mutual protection. A condition of this kind once established in India has a very good chance of enduring for centuries and receiving at last an almost religious sanction from immemorial use. The Maratha cultivators clustered in their clumsy earthworks for generations after peace was restored. Nothing could have dissolved the practice but a new series of conditions making it the immediate interest of each farmer to get out upon his own soil. Nothing would have distributed them except irrigation, which has accomplished this beneficent change rapidly and peacefully in many parts. A husbandman who irrigates needs to be upon his plot early and late. He must work in it at nighttime in some seasons. In point of fact he must live upon it. By these necessities communities have been dispersed over their fields, to enjoy more freedom, more light, and fresh air, as well as water. A better housed people have been better occupied, better fed, and better clothed, rendered more contented, and in other ways more civilized; the whole of their life has been lifted a little by raising its material base. This has been accomplished under the very eyes of all observers in the present generation by means of irrigation in the Maratha country.

The Bombay code of water laws are rigidly enforced, so that when "water runs upon any land through an illicit breach all those whose farms are benefited are fined in double rates, and if no land is benefited and water is allowed to run to waste, then those to whom the channel is carrying a supply are held jointly liable. These general penalties are, of course, only inflicted when no guilty person or persons can be discovered. Those who benefit by means of a percolation through the banks, or whose wells are within 200 yards of a canal, are required to pay for the advantage conferred on them without their request. Summary powers are taken for the recovery of arrears." The rules, though severe, are considered just, and generally the penalties are accepted without murmuring.

The canal system of the Panjab and Sind are among the most important and extensive in the empire. The figures alone will establish this. Many ancient works of great size, dating back from the twelfth and thirteenth centuries, are still in partial operation. The British began the work of repair, reconstruction, and new creations as early as 1821, when they took the old Delhi Canal in hand, making modern changes thereon. It was the famine years of 1831–'32 that first aroused them to greater activity. In 1821 this system served only 20,000 acres, while in 1831–'32 it had increased to 94,000. By 1847 $590,000 had been expended upon it; in 1889–'90, this had reached the sum of $1,598,400. The West Jumna Canal, which begun as a new work in 1875 to take the place of old and useless channels, has cost up to 1890 $8,000,000. There are 84 miles of main channels and 1,110 of distributaries, a total of 1,200 miles. The East Jumna Canal was projected in 1830; in 1837–'38, its construction saved $9,600,000 in crops threatened by drought. By 1889–'90 these two systems had returned the interest on all the expenditures and $480,000 besides. They had made secure an area of 2,000,000 acres, which paid the Indian Government a land tax or rental of $96,000,000. A new school of hydraulic engineering has been created by these great works, and the engineers trained in them are the foremost irrigation authorities known to the world. The Doab Canal belongs to this system and section, running parallel with the Jumna River for 450 miles and inclosing an area of 20,000 square miles. The main canals are 130 miles in length and the distributaries 1,112. There are 850,000 acres "under ditch," 580,000 that can be cultivated, and 250,000 that were served in 1889–'90. The total expenditures for irrigation purposes in these provinces represent a British investment of $36,400,000, and a total irrigated area of about 6,000,000 acres, of which one-half is under regular cultivation each year. These works have for sixty years paid an annual return of at least 8 per cent.

Of other systems the Agra Canal has a total length of of 709 miles, 109 of which are main channels. There are 700,000 acres under ditch, of which total 178,000 acres were cultivated in 1889–'90. The Dun Canal is 75 miles in length, serves 25,000 acres and cost $277,400. The Rohillkhand Canal has 357 miles of channels and 196,000 are regularly irrigated. The Behar Canal with 500 miles of channel has cost $1,116,800. It serves 150,000 acres, of which, in 1890, but 24,000 were cultivated. The total expenditures under the British direction, in the Panjab, Swat, Sirhind, Sind, and the sub-Himalayan region, for irrigation purposes has not been less than $64,000,000. Not less than 2,500 miles of channels were in operation during 1890. In the sub-Himalayan region many private canals have been constructed, which, from the rudeness of the work done, the Government discourages in every way, buying them out whenever it can. All the river channel banks are cut to let the water flow out, a practice which is very wasteful. Rude embankments are thrown up at favorable points to catch the rainfall. It is the practice of these native speculators in water to sell their supply for one quarter of the crops grown under their service. The whole region abounds with wells, usually only rude holes of small depths, protected by brushwood casings. The water is lifted by man and bullock power and gives from 4,000 to 6,000 gallons each twenty-four hours. The Government officials endeavor to induce the ryots to make new wells and brick up or otherwise improve their old ones. When they do so there is a considerable reduction made in land rent, or other rewards are given. Contrary to the American practice, the Indian engineers prefer water free from silt or deposit generally. They not only like to apply clear water to the land, but they are generally favorable to lifting from stream instead of flooding the water direct from the ditches. Hence serious encouragement is given to systematic irrigation by wells.

It must be borne in mind that the questions waiting solution in connection with irrigation in India embrace many issues far different from those of mere engineering character; they range into the arena of imperial powers, the defense of vast possessions, the security of dependent races, and their training as indispensable factors in a contest for industrial and commercial supremacy. The Anglo-Indian disposition of the ryots or peasants communities determines the character of Indian competition in the food markets of the world, a matter of significance to American farmers. Hence the following account of the policy and procedure adopted in the Panjab and the Sind country, the region of wheat, will have more than a transient interest. Mr. Deakin describes settlement under one canal, as follows:

> Under the Sidhnai Canal there were 118,000 acres of Crown land, of which 41,000 were capable of being watered. Accordingly in 1886 the problem of securing its occupation faced the Government of the Panjab very seriously, since there was then but one-third of the 64,000 acres irrigable from this scheme in the hands of cultivators. The process of settling an agricultural population upon waste lands hitherto uninhabited, and which can not be cultivated without artificial irrigation, is both difficult and peculiar. In some respects it is analogous to the foundation of a colony, wrote the finance secretary in his letter to the central Government in that year. The returns for 1889–'90 show that nearly 61,000 acres were actually watered in the kharif (summer) season, and though 10,000 acres of this received an impefect supply it is evident that the whole tract has been brought under the plow during three or four years. The same practice has been pursued under the Sirhind system with equal success, while the Chenab and Jhelum projects are avowedly undertaken in order to water large areas of outlying lands, which will require to be settled before the canal supply can be utilized at all. Considering the recess to be dealt with and the prevalent dislike, of the farming castes especially, to leave their districts, the new task imposed upon the officials is by no means simple. They are required to build up from the very rudiments, to settle a population, to attract cultivators, to provide for the foundation and management of villages, to organize and pay the ordinary rural agency, and in fine to establish the whole economy of a new society. The country west of the Satlej at Fazilka was dry, barren, and desolate until the construction of the Lower Sohag canal, since which 50 villages have been created, with over 60,000 acres of watered land among them. In this respect, therefore, the province has undertaken a special and arduous work in connection with its irrigation. It is encouraging to learn that it is being pursued to-day with triumphant success. The annual value of the crops grown on two of the smaller schemes is estimated at upwards of £300,000, reaped from country which a few years before maintained nothing but a few goats and black sheep.
>
> The conditions of settlement differ in minor respects under different canals. The rajbahas, or branch channels, of the Sidhnai supply distributaries with an average length of 2 miles, commanding about a mile of country on each side, or about 2,500 acres in all. This is made the village block, but of course the size varies somewhat under other circumstances. Each block under the Sidhnai was surveyed into squares of 22.5 acres, and four of these, or 90 acres, was allotted to each settler. This is larger than the usual holding in the province, but was made so to encourage applicants, and also to induce them to undertake the expense of sinking a well and of maintaining cattle to work it, which is only possible in the Panjab for what may be termed well-to-do farmers. A five years' lease was given of each allotment, the charges being 1*s*. 4*d*. per acre cultivated, 4*s*. 6*d*. per acre watered in spring, and 5*s*. per acre watered in autumn, with 3*d*. in the shilling for village officials and local rates. The digging of a well means a reduction of 2*s*. 4*d*. a year per acre watered by it for twenty years; 1*s*. in spring and 1*s*. 4*d*. in autumn. The rent for the 90 acres is £1 a year, and the holding can be purchased at 6*s*. an acre, or £27 for the allotment, after the expiration of the lease. The covenants inserted are something like those attached to the preliminary licenses and leases granted to Australian free selectors—no transfer or assignment

is valid without the consent of the department; one-half must be cultivated within three years and two-thirds within four years after possession is given; a proportion of the cost of any irrigation channels constructed has to be paid, and all minerals are reserved. Not only does the State not bind itself to supply any water, but an addition is made in the shape of a declaration that nothing in the deed confers any "right, title, claim, easement, or privilege whatsoever to or in respect of any water," a condition which would be of enormous value to the Australian Governments if it had been inserted in all grants from the early days of the colonies.

In the Indus Valley there are many small canals, each 8 to 16 miles in length, with a total length of 709 miles, supplying water to 214,000 acres, which area was under cultivation in 1889–'90. Three other important perennial canals supply in all 411,000 acres, and have a total length in channels of 1,479 miles. The Lahore branch of the Bari Doab Canal irrigates 523,000 acres at a cost of $1.60 per acre and a duty of 243 acres each second. It supplies, also, the water needed by 1,352 villages. The cost of these works by 1889–'90 reached a total of $7,872,000. The year's net proceeds of the water supply to the administration was $873,600, while the expenditures were but $288,000.

In the province of Orissa, with an area of 24,000 square miles and a population of 4,250,000, there are hundreds of miles of irrigation ditches, and 250,000 acres under cultivation from them. In 1889–1890, 511,000 acres were under the canal system and ready for cultivation. In 1866, there were but 60,000 acres available. The rivers of Orissa are affected by perennial floods, the effect of which is felt in the natural subirrigation of about 3,000,000 acres.

The independent or native states of India afford to the observer and student problems in irrigation of a most interesting character. They comprise two-thirds of the peninsula, and offer every type of industrial condition from the advanced state of Mysore to the semi-savagery of the fighting hill men. From the point of irrigation and agricultural activity Jaipur is the most advanced. It contains an area of 14,463 square miles and a population of 2,500,000. There are 108 separate systems of irrigation works, having 364 miles of main canals and 422 of distributaries; in all 786 miles. There are five storage reservoirs, the largest of which covers an area of 6½ square miles. The cost of these modern works has been $1,516,800, and the revenue for 1889–90 was $140,080. In addition to these new constructions the administration of Jaipur has restored and improved 300 native or village tanks, serving 30,000 acres, at a cost of $720,000, upon which the return is at least 4 per cent.

In the native state of Mysore there are 1,000 miles of irrigation canals, main and distributing, with 20,000 village tanks. The little state of Kotah has one well constructed canal system having an extent of 180 miles and serving 50,000 acres. But the greatest proposition of irrigation work in upper India is accomplished by other means than those of canals. There are many thousand rain-fed tanks and wells, small diversions, and temporary dams, with a large number of petty storage areas, made from interior streams and sudden showers. It is impossible to obtain the statistics of these native works; even under the imperial administration the returns are very imperfect. In the more advanced native states there is a systematic encouragement of small works. When built by the state for the ryots, they are required to pay annually a fixed assessment. Remissions are made when seasons have been bad, but with far less liberality than under the imperial rule.

Without doubt the notable features of British Indian irrigation administration are: (1) The large and systematic extension of state aid; (2) the favorable policy on land and water management adopted of late years to aid the peasant or ryot population; (3) the thorough and costly character of works in certain commanding areas of agricultural activity; and (4) the active and comprehensive manner in which the Anglo-Indian authorities and engineers are aiding in reconstructing the native and village systems of irrigation by means of wells, tanks, and other small, but independent appliances. It will be impossible to make more than a reasonable guess at the extent of the phreatic irrigation appliances in British and native India; still it will not overstep probable limits, but indeed be well within them, to estimate that at least 300,000 shallow wells are used on the Indian peninsula for the purpose of irrigation and cultivation; allowing 20 acres per well this will give 6,000,000 acres as under cultivation thereby. It is in all probability nearly double that area. The following partial table of returns found in Indian water-supply reports illustrates this statement:

Name of district.	Number of wells.	Irrigated land.
		Acres.
Gupanwala district	8, 195	163, 916
Gurdaspur district	5, 000	100, 000
Kándesh district	9, 690	193, 800
Ludheana district	1, 157	23, 148
Madras presidency	85, 000	1, 700, 000
Mainpuri district	15, 178	303, 573
Meerut district	14, 569	291, 395
Mongbyr district	3, 500	70, 000
Nellore district	671	13, 420
Punjab district	50, 000	1, 000, 000
Umbala district	3, 267	65, 341
Total	196, 227	3, 924, 563

A serious effort has been made to obtain a correct statement of British investments in Indian irrigation and reclamation works, but it is not claimed to be a success owing to the difficulty of separating with accuracy the several aspects and items of the great accounts that are involved. But taking only the stated construction items, a total of $165,956,560 is obtained. The total area of cultivation under irrigation in the imperial provinces is not less than 25,000,000 acres. With the irrigated areas of the native states, which, large or small as they may be, will aggregate 8,000,000, we shall have a total irrigated area of 33,000,000 acres. This estimate is given upon the basis of one crop per year and can be considerably increased if credit be given for "rabi" or winter cultivation. In any event the policy adopted is comprehensively great in its magnitude, and the results achieved are massively great.

The area under wheat as affected by irrigation is a matter for serious examination. According to Prof. Wallace, of the University of Edinburg, who is considered an authority, there are at least 30,000,000 acres under wheat, of which 20,000,000 are in the provinces, while the remaining third are found in the native states. Prof. Wallace states that in his opinion at least 80,000,000 more acres may be reclaimed, and Mr. Alfred Deakin writes in the Melbourne Age:

> There are some millions of acres still available for wheat growing by dry farming in Central India, only waiting for population and railways to become largely productive. Both these wants are likely to be satisfied. The people will steadily flow to them from the many congested villages of the northwest, and the enterprising Government of India shows no signs of relaxing its spirited policy of railway construction, so that a gradual increase in the production from this quarter may be looked to for years to come.

The wheat area affected favorably by irrigation is not less than 15,000,000 acres. Mr. Deakin continues by saying:

> Without taking into account what the natives may be able to add by means of new wells and tanks, it is certain that the Government schemes will increase the extent of the wetted lands considerably within the next ten years. There are 10,000,000 acres under wheat in the Punjab and northwest to-day, while the new schemes in the former and the great Sarda project in the latter will probably add another 3,000,000 acres to the irrigated area. The regularity and largeness of the yield from these lands makes them a formidable addition to the Indian total. There is also a considerable acreage watered in which wheat is not yet grown, but upon which it would be grown at once if prices were sufficiently tempting. In the two provinces mentioned the possibilities of wheat are limited only by the possibilities of irrigation. Probably a considerable portion of the uncultivated acreage elsewhere would require a system of water supply to make it permanently productive. The construction of the required works will demand time as well as money, and probably not more than 5,000,000 acres, counting Government and native schemes together, is likely to be added during the present generation to the irrigated area available for wheat.

It is evident from all statements and estimates that the policy of the Anglo-Indian, especially from the standpoint of irrigation security, is one that will need to be seriously reckoned within the food markets of the world.

THE ISLAND OF CEYLON.

The government of Ceylon, beginning in 1875, a practical work of irrigation restoration, has wisely as well as of necessity adopted some of the ancient systems of works and water usages. The irrigation problem has become therefore a very interesting one. As in British India the government is really the chief, or, according to Judge Stephens, the only landowner. In this the British rulers are following the general economic law that underlies all Asiatic and ancient civilizations. It is the opinion of many close students of economic science in connection with general history that a large proportion of the disorder and conflict that has arisen in Asiatic countries which have passed under European control is often the result of unwise because ignorant attempts to remold primary and institutional forces like the ryot or peasant control of the soil under general law or custom, into conditions more like those of landlord and tenants, such as in Europe, and especially in Great Britain, are in operation. British India has suffered greatly from a failure to recognize the fact that the Zemindar class created by Mohammedan conquerors, were not landowners or landlords in the English sense, but collectors from the ryots of the land tax required by all native governments. The more recent and systematic recognition of these ancient relations to the land combined with the vast system of the public works, and especially of irrigation enterprises designed as a protection against famine, tends rapidly and very greatly to strengthen the British administration of India by making it industrial, ameliorative, and beneficial. As India is one of our most formidable competitors in the agricultural markets of Europe, it is well to understand the forces that go to make security there. Another peculiarity which, as it is identical with irrigation works and their maintenance, deserves mention. It is the old system of enforced labor modified and controlled as a local necessity. Of course money or currency, as we understand the terms, has never been of potential force in Asiatic or other countries whose wealth is fixed and immobile in character. If Hindoo or other Asiatic communes or villages have had work to do for the public benefit, they do not as a rule collect taxes and hire labor. They employed themselves to do the work needed, and the government is compelled to offset this against other dues of produce or money. In this way the "corvee" system survives and can not be effaced. As much as British officials dislike it, they have been compelled to recognize the same, especially in Ceylon, the Panjab, Ouhd, and elsewhere in Hindostan, while leaving the village communities to be benefited to regulate the service themselves. We can see a "survival" of this practice in New Mexico. The Mexican irrigationists are everywhere hostile to the creation of new and better systems of works, as is proposed for example in the Mesilla Valley, because the American organizers propose to substitute a small annual payment of $1 or more per acre in place of the three days' labor generally given per year under the call of the majordomo or water master for the repair of "zanja's" and "acequias."

The Ceylon authorities, availing themselves of such native customs, have for some years past been doing excellent work in the way of reorganizing and enlarging the irrigation system of that island. In one of a series of valuable papers prepared by the Hon. Alfred Deakin, M. P., of Victoria, and published during the year 1891 in the Melbourne Age, there is a full account of the course adopted. The task of the central board is declared by him to be one of no early or easy fulfillment, and he quotes their object as stated in a board report:

> It is to the gradual and patient renewal of the ancient irrigation systems of a whole district, utilizing every drop of water available that our efforts should be directed. It is by this means that the crops of a district are multiplied many fold and secured from failure; that many forms of disease and extreme want are banished; and that the health, wealth, and comfort of the people are permanently assured.

Mr. Deakin states that—

> Every village in the island had possessed for centuries a kind of assembly of notables and elders, to whom all questions of common interest were referred. The absolute necessity for joint effort in connection with irrigation had been felt, and at a remote period a complete system of administration had sprung up, of which the tradition remained where the works had been destroyed, and the practice where they were still in existence. All land holders were compelled to do their share of repairs or else they were refused water. They were forbidden to irrigate fresh fields unless there was a surplus available, and in a season of drought were allotted only a fair proportion of the diminished stream. The rotation of watering and the order of supply were strictly determined, and thefts of water or breaches of custom promptly punished. This communal system was readily revived when the need arose.

It is also noteworthy that the governor, Lord Grey, who from 1846 to 1857 seriously began the consideration of irrigation restoration in Ceylon, also suggested the idea of municipal district organization with local responsibility and the direct bearing of cost by the individuals to be benefited by water storage and distributory work. Substantially Lord Grey's recommendations proceeded and embodied the same ideas and principles that have since been established, with modification of scope, details, and plans, in Cape Colony, South Africa, in Ceylon itself, in California (by the Wright district laws), in Victoria and New South Wales, and later still in whole or part in the States of Nevada, Washington, Kansas, and South Dakota. The Ceylon policy is more conservative than that of the South African and Australian colonies, or of British India, so far as state aid by loan or gift direct is concerned. It is not of course as radical or thorough, in the sense of local self-government, as the municipal district system of California, but it is very simple and efficient. As has already been shown irrigation works in Ceylon, are very ancient, some still in partial use, being dated back to 500 B. C. They are also very complete, existing throughout the island, except in the central mountain district. The Mohammedan rulers in the middle centuries of the Christian era enlarged them greatly. The later Portuguese conquerors neglected them entirely, and the Dutch mismanaged them. The British began to repair them in a desultory way at the beginning of the present century. For the last thirty years they have worked to great advantage, as may be seen by the fact that the population, which was but 750,000 persons when their rule began, now numbers over 5,000,000. In 1857, Governor Sir William Ward, revived the ancient communal custom of obtaining and regulating water supply. The nature of the works required and their management were to be decided upon by a two-thirds vote of the landowners or farmers in any proposed district. This plan was extended in two periods of five years each over the rice plantations. In 1867 Governor Sir Hercules Robinson, carried a measure which provided for a vote of the landowners for and against the establishment of irrigation districts, and for their control by village council or headmen under by-laws supported when established by penalties. Most important was the authorization of a money advance by the state for expenditure upon private lands. Expenditures for minor works were locally authorized to the amount in each case of about $500. In larger works, requiring combination, the farmers can borrow from the government without interest on ten years' time, to be repaid by 10 per cent installments. Up to date (1890) the amount of such loans have been £543,000 or about $2,606,400 ($4.80 per pound). In 1881, the village or landowner control was modified by ordinance so as to provide for a central board and for provincial bodies of government officers and native landowners. In deciding on local works and regulations, the votes of two-thirds of all farmers owning or renting land and representing one-third of the area to be irrigated, or the votes of those owning two-thirds of the acres to be irrigated without regard to the number of persons, are necessary to settle conditions and secure loans. In the construction of works, always under government engineers, the exact cost, not the estimated, is charged against the community. In preparing plans, £250 may be expended by provincial boards. If a larger sum is required, the matter is referred to the central board. The funds appropriated are equitably assigned among the provinces. If the farmers, as has been found advantageous in many cases, are willing to perform the whole or part of the work required, they are granted certain offsets in payment. Land may be acquired as compensation. The government will maintain all irrigation works, at a cost of about 5 cents per acre per year. A perpetual maintenance can be had by a payment not to exceed 24 cents per acre. The government loan is a first charge on all lands, and the same can be sold if the farmer is in default. It may be borne in mind, in considering the financial side of this policy, that the British authorities collect rent for the land and excise duty on rice, so that the great increase in revenue in both directions that has already arisen from the security in crops derived by irrigation works and management, is more than ample compensation for the non-interest loans that have been made. The works restored and repaired are principally to serve the rice or paddy fields. A considerable area has also been added in coffee, cinnamon, tea, fruit, and other crops.

The extent of the ancient irrigation may be realized by the statement that the British authorities have already restored (1891) 2,250 small and 59 large tanks or reservoirs; they have also constructed 245 weirs or "anicuts," as the Indian engineers call them, with 700 miles of main canals. The several areas reclaimed range from a few hundred up to 10,000, 23,000, and 25,000 acres in extent. The restoration now planned in Ceylon will it is estimated cost £500,000. There are over 5,000 ancient reservoirs in the island, some of them of immense capacity. One king in the twelfth century is credited with having constructed 4,770 tanks and 543 great canals; also repairing 1,395 large reservoirs, 960 small ones, and 3,621 canals. No snow falls in Ceylon. The rain fall on the coast is 88.85 inches; on the low areas back of it, where the principal crops are raised, it is 23 inches, and on the mountains the fall is 217 inches per annum. This statement is based on an average of nine years. The duty of water is low, as rice is a thirsty crop, and the cost is put for the paddy fields at $24 per acre. The revenue derived from the irrigated areas in rents, etc., is stated at $1,500,000. The annual land taxation is £500,000, of which rice pays three-fifths. The total area under irrigation works is given by the Government at 574,000 acres, and by Ferguson's hand book at 700,000 acres.

The origin of the tank system is lost in the impenetrable mystery which obscures the history of the Asiatic races; but the evidences of their antiquity are presented in the solid masonry and concrete of ages. The village tank is only second to the temple in every East Indian village, and its waters are preserved with as much care as the idols; for indeed it is wholly necessary for the health and the sustenance of the people, as well as for the celebration of their religious rites. Commencing in Ceylon, we find the tank system in a fair state of preservation. The laws governing that system in India are necessarily communial, and all the natives who use the water are bound to contribute to its production and preservation. These village tanks are found by the score of thousands in every province or dependency of the British Indian Empire. The report of the Ceylon Central Irrigation Board for 1888 has an interesting account of the system in that island, from which the following extract is made, with a plan showing mode of distribution:

> The village tank, however, was the most ordinary form of water storage, and although there were more or less important differences in the mode of making use of its supply, and of apportioning the fields under it, there was a general resemblance on these points throughout the island, and the diagram on the opposite page of the arrangements for cultivation under a tank in the north central province, where ancient customs have perhaps been preserved with less alteration than in any other part of Ceylon, will give a fair general idea of similar arrangements throughout the island.
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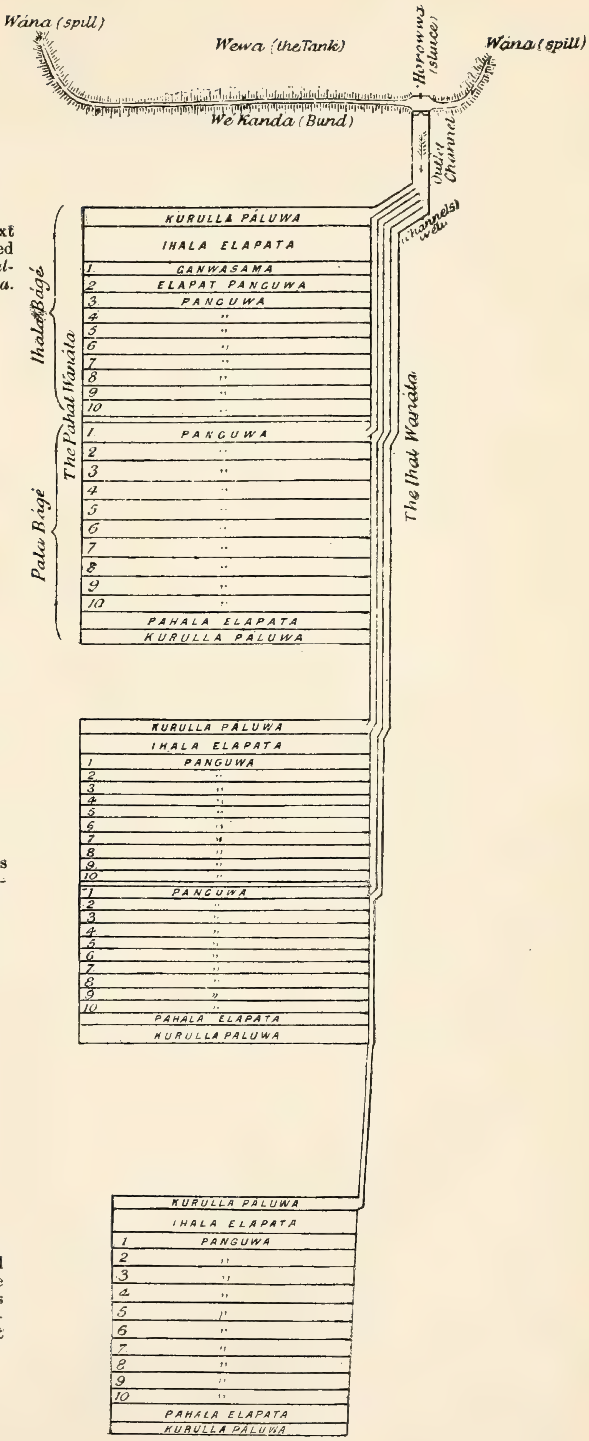
> The general customs according to which land under an irrigation channel in Uva were worked have been described by Mr. Bailey, from whose report it appears that all holding land benefited were bound to take an equal share in the repairs of the irrigation channel. Each proprietor was responsible for the proper repair of a certain portion of the channel, and sudden and unforeseen accidents were repaired by the joint labor of all, as was also the dam, or, in the case of a tank, the bund. No person was entitled to water if he neglected to contribute to the repairs of the dam or channel, and no new land could be cultivated to the detriment of the existing fields. The fields at the end of the channel were plowed first, and the rest upwards in regular order; and if the lowest fields were not plowed at the proper season they lost their right to priority of water. During the dry season the fields were irrigated by rotation, commencing with those at the commencement of the channel (or nearest the bund, as the case might be). When the volume of any supplying stream was insufficient for the irrigation of all the lands dependent on it, they were divided into portions of such extent as would admit of each being properly irrigated, and these portions received the whole volume of the water during succeeding seasons in rotation. The channel was inspected daily, and if any field were found irrigated out of its proper rotation the proprietor was held guilty of theft of water. Any violation of these regulations was promptly punished by whipping or fine, and if a royal prison was at hand, by imprisonment also.



The fields next the tank are called *Purampota*, or *Mulpota*, or *Upayápota*.

The next range is called the *Hérenápota* or *Peralapota*.

The land opened in addition to the above two ranges is called Kaṭṭa Kaduwa or Alut Aswẹdduma.

THE AUSTRALIAN COLONIES.

The government of New South Wales expended up to 1890, $389,320, for the improvement of the Darling River, in order to utilize the same for both irrigation and navigation.* The Murray River improvements have been conducted chiefly by the Colonies of Victoria and South Australia. On all the important western rivers of New South Wales, the late Consul Griffin writes that—

> Irrigation is carried on by pumping, and for this purpose centrifugal pumps are used almost exclusively. The engines for working them vary from 8 to 10 horse power, and at one place the engines used are of 80 horse power. In nearly all cases the water is distributed in earthen channels excavated with plows and scoops.

H. G. Kinney, C. E. and government engineer for New South Wales, estimates the water available in the Murray basin for that colony at a service of 800,000 acres. The supply from the Murrumbidgee is estimated at 500 acres, making a total of 1,350 acres to be irrigated in New South Wales by the two rivers. Making deductions for use in other ways—domestic and stock—the irrigation area is placed at 1,080,000 acres. The annual rates for water rental are put at from $2.44 to $4.87 per acre. An extensive canal projects known as the Murrumbidgee Southern Canal System, is under consideration. It will embrace six main lines and three branches, with the use of Urania Lake as a reservoir. The main distributories will have a total length of 838 miles, and the cost is estimated at $6,669,746. Mr. McKinney's plans for the utilization of the Murray embrace a canal system of 240 miles in six divisions, at a total cost of $7,863,535.

The colony of New South Wales has not passed as yet (1890) any of the comprehensive legislative bills proposed by the royal water commission of 1888. All river and stream dams in the colony exist by sufferance only. As a result, when cut, as they sometimes are, by parties living below them, there is no legal means of redress or of deciding issues.

In Queensland the supply and conservation of water is being developed most directly by the systematic use of the drill in boring for artesian water. The "water supply" department of the colony has pushed work in a most energetic manner. J. B. Henderson, C. E., who is the government hydraulic engineer, in his report under date of Brisbane, September 23, 1891, says that—

> In selecting sites for artesian wells, one object aimed at has been to test the water-bearing capacities of as large an area of the colony as possible; the bores completed and in progress have therefore been placed in what are considered the most favorable positions for this purpose.

He adds that "marked success" has attended these efforts; that they have created much general interest in "water conservation," and in the scientific and practical questions involved, and that they have been helpful in the encouragement of private enterprise and investment in the same direction. In these respects the "artesian investigation" and "irrigation inquiry" ordered by the Fifty-first Congress have caused the duplication of this Australian experience.

Since such drilling for artesian water begun under colonial authority fifteen bores have been sunk by the Queensland department of water supply, each averaging 1,571 feet, and only one can be called a failure, according to Engineer Henderson's report. Three of the fifteen have been abandoned by the contractors. If their work had been completed no doubt is felt but that an artesian flow would have been tapped.

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* Special Report on Foreign Canals and Irrigation, State Department, p. 72.

The total amount of expenditure up to June 30, 1891, is given by Mr. Henderson at $1,246,959. The amount appropriated for "water storage, main roads, and artesian wells" is given at $1,713,600. Of the total expenditures all but $396,519 is credited to direct cost of water supply. There are 33 artesian or well bores named, 3 other wells, 25 tanks and dams combined, one each of overshot dam, tank, and water supply, water hole, trial shaft, and bore shaft. In all there are 77 works under Government control. The greater proportion of these works are of course used for watering stock, some irrigation is accomplished by the artesian water, and domestic service is obtained in several cases. The total number of Government artesian well bores is 15, of which 8 are flowing. The amount of flow runs from 8,228 to 3,000,000 gallons per 24 hours. The 8 public wells in use flow a total of 4,613,428 gallons per diem. The depth of well bores made runs from 323 to 3,262 feet. There are seven ranging from 1,002 up to 1,781½ feet, and three whose depths range from 2,000 up to 2,512. The railway service (Government) have bored one well with artesian flow. The temperature of the water ranges from 77° to 124°, and the surface pressure from 5 to 185 pounds per square inch. There are eighty-six successful private bores or artesian flows. These wells seem more generally successful than the Government operations. No failures are reported. Eleven are reported as "rising in bore," three having "only a very slight surface flow," and of several it is stated, "no particulars to hand."

These are pumped up at depths of from 12 to 70 feet. In three cases water struck in bores was from 1,900 to over 2,000 feet from the surface. There were, at the close of June, 1891, sixteen artesian (private) bores in progress of drilling and twenty-five proposed. The map shows eight successful (Government) artesian wells, two as in successful progress, and twelve as in various stages.

The regulations for watering cattle, etc., at the public wells or supply stations provide as follows: Charge for horses, 3 cents per head; cattle, 2 cents; sheep, 50, 12 cents; 100, 18 cents; each additional 100, the same. The extra amount charged must be paid by the person in charge of the animals. Drovers are given a traveling permit for use on the public stock road, and the caretaker at watering station may refuse water unless the stock has traveled for sixty hours after one watering.

The area to be served by irrigation works in progress in Victoria is about 500,000 acres. The amount of money loaned to irrigation trusts is about $7,000,000. The area actually cultivated will not exceed 30,000 acres. In New South Wales the amount irrigated in small parcels, such as gardens and orchards, will not exceed 3,000 acres. Provision is now being made under Government aid for 38,000 acres. The plans of the Government engineer, Mr. McKinney, cover a great area, and will embrace 1,000,000 acres.

In South Australia the colony being organized on the Murray River by the Chaffey Brothers, under convention with the Colonial Government, is designed for the ultimate reclamation of some 200,000 acres. There are probably 5,000 acres in the colony now under cultivation by irrigation. Some effort has been made in the direction of boring for artesian water, but without success now or any great promise for the future. This statement is made on the authority of Mr. Edward William Hawker, of Adelaide, who has recently visited the United States as commissioner for the colony on irrigation and water conservancy.

CAPE COLONY.

The water courses of South Africa are cousins german to a majority of those in our own arid region. They are for a large portion of the year dry-stream beds, but like our own streams rapidly assume a torrential character during the rainy or snow melting season. In Africa it is wholly rainfall, however. The physicial aspects of the interior are not unlike much of our southwestern sections—high table-lands and mountain plateaus, treeless to a large extent, and almost constantly subject to drought.

Irrigation has been primitive, and sporadic and individual in character, where practiced in Cape Colony, among the Boers, the Free Orange State, and the South African Republic. In 1877 the Colonial Government organized a district system as follows:

Any three or more landowners, with a given area where it is proposed to store water for irrigation purposes, may petition for the proclaiming of such irrigation as an irrigation district. The petitioners must own not less than one-tenth of the land to be embraced. A Government engineer is then sent to attend a landowners' meeting and report to the governor on its practicability. If favorable, the district is permitted. The landowners then choose a board of management, which is invested with corporate powers. Each $2,500 in land value is represented by one vote. This board has the charge and conservation of all natural waters that rise and flow over or by their nature are common to two or more owners. They have the absolute control of all waters artificially stored and distributed, are given full power to do all the work and construction necessary for the highest use, with the legal right to levy taxes, etc. Land not improved nor irrigated by the district works or supplies shall not be so taxed. The board may borrow either from private means or public funds. In the latter case the loan may be to the extent of one-half of the land value within the district. Public money may be loaned for irrigation improvements to private landowners under due forms of law, to be a preferred charge on their land at 8 per cent for the term of four years. Mortgagees may join in the application, etc. There are provisions regulating appropriations, arbitration, pollution, or obstruction of flow. Another law, passed in 1879, provides for irrigation loans to municipal bodies. Another and more favorable act was passed in 1880. By this legislation the Cape Colony became the first community to adopt the modern system of irrigation districts, as municipal and land owning or communities, formed to own, control, construct, use, and manage waterworks. Scientific surveys inquiries are now in progress for the determination of storage sites and and their relations to water supplies. Irrigation is everywhere a success, so far as it is now in operation. Borings for water have not been attempted to any large extent, but success has attended all efforts made, and public interest is aroused in the possibility of phreatic supplies. United States Consul George F. Hollis, of Cape Town, says, under date of 1889:

> The most complete storage work completed in this colony and the most important is that at Van Wycks Vley. The rainfall in this section is very irregular, the average for eleven years having been 10 inches, and in some years falling to 3 and 4 inches. The reservoir has depended on the catchment area of, say, 240 square miles. This has been found to be insufficient, and a furrow is now nearly completed through which the water of a neighboring river will be brought in, by which it is estimated that the water-covered area will be increased to 19 square miles, with a depth of 27 feet. The land under irrigation is held by the Government, and is leased at a minimum price of 10 shillings per acre. The bailiff in charge has the sole control of the flow of water, and uses his discretion in its supply, some land within the area requiring more water than other portions. Owing to many causes, the chief of which was

ignorance of the character of the land, fostered by the report of interested persons, who declared that the water would be too salt for agricultural purposes and who desired the work should fail and be abandoned, giving them a chance to acquire it, the poorest tenants, assisted by the Government supplying seeds, were alone secured. Their success has, however, been so marvelous that the lands will soon be eagerly sought after. It is estimated that last year 1,300 acres were irrigated, at an expenditure of an inch of water per month from the surface. The rainfall over the whole colony is so irregular that I have taken the subdivisions of the colony for the purpose of comparing, and have summarized the reports from an average of six stations in each district. The rainfall for these districts for the year 1888 was as follows:

No. 1. Cape Peninsula	53.84	No. 7. East Central Karroo	10.15
No. 2. Southwest	32.95	No. 8. Northern Karroo	11.43
No. 3. West Coast	15.18	No. 9. Northern Border	8.84
No. 4. South Coast	33.60	No. 10. Southeast	28.17
No. 5. Southern Karroo	17.59	No. 11. Northeast	20.39
No. 6. West Central Karroo	14.12	No. 12. Transkei	25.00

The topographical features of South Africa are so peculiar that the system answering for one district is not applicable to others, while the rainfall varies greatly as one leaves the coast and ascends to the various table-lands. In general it may be said that. the land being almost entirely denuded of trees and bush, the rain is not drunk up by the soil, but runs rapidly over the surface, seeking its natural outlet to the sea, while the evaporation is very great, estimated at 6 feet at Van Wycks Vley, necessitating deep storage basins.*

SUGAR PLANTING AND WATER CONSERVATION IN DEMERARA.

Irrigation is not practiced systematically in British Guiana, according to the report of United States Consul Walthall,† but the storage and conservation of water is thoroughly worked out, and in seasons of drought at least the sugar planter is not without the means of supplying the lack of natural precipitation. The following account of the management of the sugar estates is worth studying by our Louisiana planters:

The average estate in Demerara has from 1,000 to 1,200 acres of cane under cultivation, while the largest estates exceed 2,000 acres.

The area of cultivation on each estate is generally divided into small fields of 10, 15, or 20 acres. The work of planting these areas is only necessary every four years or thereabouts, while the crop is reaped every fourteen months. To plant a large estate with sugar, cultivate it, harvest it, and manufacture it into marketable sugar requires necessarily a comparatively large number of laborers. These are free black natives, Portuguese, and Chinese, although the majority of laborers are from East India, better known as coolies, who are brought out from India as indentured immigrants under a five years contract at the joint expense of the colonial government and the planter in the respective proportions of one-third and two-thirds. This class of labor is counted most profitable. The laborers are divided into gangs known as follows: First, the shovel gang; second, the weeding gang; third, the creole gang, employed to transport plants from field to field, manure, etc. The duties of the weeding gang are performed by the men and of the other two by women and children, the rate of wages being, men, 24 cents (1*s.*); women, 16 cents (8 *d.*) per day.

The drainage system should be and generally is most complete. The water supply for both navigation and irrigation is obtained from a fresh water canal which runs along the rear. A sluice gate is constructed on the dam of this canal, and when water is required it is opened and the water pours into the trench. The transportation of canes from all parts of the estate, coals from the river and railway depots to the buildings, is done entirely by punts drawn by oxen or mules. The main navigation trench runs from the river up the center of the estate and is intersected at short distances by cross trenches and branch water ways, affording water ways for transporting canes cut at a distance of several miles from the factory to their destination by water. This, and nearly all other estates in Demerara, front on the sea or river, and are a source of constant trouble, anxiety, and expense to the planter, for their dams are frequently bursting, which has been known to do damage to the amount of £10,000 or $48,600. A sugar estate in complete working order, and with 1,200 acres of cane under cultivation, is worth about $72,900. The cost of producing a ton of sugar, interest on capital invested alone exempt, is £12 or $58 to £14 or $68. First sugar sells at from £19 or $83 to £20 or $97 per ton. When the market realizes this price the second sugars, rum, and molasses are regarded as profits.

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*Special Consular Report: State Department; canals and irrigation, 1891.

† Ibid, pp. 327, 328.

IRRIGATION IN EGYPT.

Mr. Robert Wallace, F. L. S., F. R. S. E., etc., author of important works on "Rural Economy, Agriculture," and professor of that chair in the University of Edinburg, Scotland, recently opened his lecture course by an address on Egypt. The professor is a careful student of irrigation problems, and has represented agricultural interests by an official appointment to study the same in this country, India, and Australia. His recent address gives such a clear and succinct account of Egyptian practices and results that extracts are made. Mr. Wallace states that for agricultural observation the best time to visit Egypt is from August to October. He said:

The mighty Nile, already much swollen, continues to grow toward its full flood and full measure of usefulness and wealth to the industrious cultivator; the cotton crop, by far the greatest source of wealth, gradually and by successive stages reaches maturity; the maize or "dura" crop assumes strength and acquires importance both for man and beast; the sugar cane makes the most rapid progress in its bulky and luxuriant growth, and the whole face of the country is alive with the distribution of rich, red Nile waters to the roots of the crops in the ground and to the land being prepared for wheat, barley, beans, "birsem" or Egyptian clover, etc. The division of Egypt is into "Upper" and "Lower." The upper province extends in a north and south direction from the province of Ghizeh, a little to the south of Cairo, to Wady Halfa, and comprises the lower part of the Nile valley, only a few miles wide, where the river has been confined within a narrow course by the barren hills of the African desert. Lower Egypt is represented by the Delta or alluvial plain, which has been aptly described as of triangular or fanlike form, with its apex to the south near Cairo. It continues to expand towards the north until it reaches the Mediterranean Sea, which forms its northern boundary. A few miles south of Cairo the Nile bifurcates and reaches the sea by two channels * * * the Rosetta branch diverging slightly to the west, and the Damietta branch slightly to the east of the direct line of the original northern course of the river. The whole cultivated area of Lower Egypt is traversed by a network of canals for the supply of irrigation water, by which alone the entire area is prevented from becoming a barren desert. Nearly the whole of the Delta is supplied by water from three great trunk canals which take off from the Nile at or above the Great Barrage Dam, which stands at the bifurcation of the river with the object of regulating the supply of water in its period of reduced quantity. The two arms of the river, together with the three great canals and various large subsidiary canals which branch from them, have been spoken of as the veins of the fan, diverging radially as they do from one important point. The land surface falls away from the river banks and from a number of the canals which were at one period branches of the Nile, so that the surface of the country presents a series of depressed natural ridges which facilitate irrigation operations and will in the fullness of time materially aid the perfect drainage of the country. The Delta in the same rough fashion has been divided into a number of irregular zones or belts of very different character, in a direction lying east and west. The first towards the north consists of a line of barren sand banks skirting the coast. The second is formed by a chain of salt lakes, some of which are above and some below sea level, covering an area of upwards of 1,250,000 acres. Zone No. 3, resting on the southern banks of the lakes, consists of salt marshes which, if drained and freed by washing from excess of salt, would produce excellent crops. The fertile belt, the shortest and widest of the series, comes next, and embraces the greater part of the crop-bearing area.

The cultivated land of Egypt proper is usually stated at about 5,000,000 acres, and it is believed that it is possible to extend cultivation in the future to an area variously estimated at from 1,000,000 to 2,000,000 acres.

The population is now given at 5,000,000, and it has been estimated that Egypt once supported 20,000,000 inhabitants. Prof. Wallace says:

> There are two distinct systems of irrigation well illustrated in Egypt: first, the old original basin system of Upper Egypt, at one time the prevailing and all but universal system; and second, the canal system begun by Mohammed Ali, and greatly extended and improved by the English engineers since 1882. In the basin system, where it is impossible to carry it on to the best advantage, large quantities of red Nile water are admitted on the land and retained by earth banks for a period of seventy days, until, by excluding air and light, it destroys the weeds, and by depositing the earthy matter held in suspension it "warps" the surface with a layer of fine mud, which manures the land for the succeeding crop. The seed is usually sown on the mud as the water retires, but at times the land is allowed to become somewhat dry, when it is plowed and the seed sown on an artificially prepared seed-bed, as in Europe. No watering is given to the crop during its growth. The improvements in this system are carried out with the object of gaining greater control over the water both as regards admission and escape. Masonry headworks, regulators, and exit sluices have been built so that it is not now necessary, as it was formerly at certain places, to periodically breach the earth bank for the passage of water. In addition to the advantages of extra control and an earlier supply of water, the expense of filling and discharging the basins has been greatly reduced.
>
> The canal system seen in Lower Egypt and on the high lands * along the Nile banks in Upper Egypt is much more elaborate, and involves much greater expense and greater engineering skill. By a series of large arterial canals, associated with a network of distributing canals, the water can be applied to the soil in moderate quantities, which are within control at any period of the growth of the crop. The great advantages of the canal system over the other are, that a greater variety of important crops, such as cotton, can be grown, and when the water is to be had all the year round two and even three crops in place of one can be taken in a year from the same land. Less water is required per crop; but canal irrigation, involving the use of clear water and for some crops especially a much limited amount of red water, does not support the fertility of the soil as basin irrigation does.

"It tends also," says Mr. Wallace, (a statement confirmed from other sources,) "to an accumulation on the surface of alkaline salts. Evaporation is greater where no drainage exists, capillary action draws the phreatic water to the surface, and with it the alkali salts which had sunk, with the application of water to the surface, or were in the soil before." Mr. Wallace holds that from 1 to 2 per cent of such salts are injurious to plant life. In the salt marsh lands of Lower Egypt the proportion is often over 10 per cent. Drainage is the only effective remedy, and with this the Egyptian irrigation department is occupied.

Surface "soakage" and "seepage" washing are employed to correct the alkali. The first requires a large amount of water. Water flowing over the land as in rice culture is to be found of service. Rice is sometimes cultivated on land not too salt for the purpose of washing out the alkali. The professor suggests that moderate areas be banked and ditched, then the water when turned on sinks into the soil. carrying down the salts, which are in a large degree drained off into the open ditches set to relieve the land. This plan is in successful operation on the estate of Drened Pasha, at Kafr-el-Daouar. Rice cultivation will disappear in Egypt under such a system, as other crops are more valuable. Rice is affected by the salts and does not produce sufficient humus for the soil. "Birsem," or clover, will correct the want of decaying vegeble matter, by the turning of two or three crops.

Canal irrigation in Lower Egypt has led to manuring with a special material that is found in the rubbish piles indicating the sites of ancient villages, towns, and cities. These contain the excreta of the millions that have passed away, which in that dry climate have been preserved. It is termed "sabach," and the piles that mark the site of old Cairo, for example, are rapidly being used to enrich the "dura" fields for miles

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* These are called "sharaqi," which literally means "cracked."

away. The foundations of old villages are also being dug up and used for manure. So also with stable and animal compost and material. The effect of this fertilization is already apparent in increased production.

The crop season of Egypt [continues Prof. Wallace] is divided into three distinct periods: (1) the winter, or "Shitawi"; (2) the summer, or "Sefi"; (3) the autumn, or "Nili," so called because it corresponds to the time when the Nile is in high flood.

During the winter, the cold weather, the various European crops, which thrive best in a temperate climate, as wheat, barley, beans, and clover (birsem), are grown.

In summer those crops grow which require a tropical or semitropical heat and occupy the portion of the land under crop, viz, cotton, sugar, and rice.

The autumn or "Nili" crops are more of the nature of catch crops, and require, as a rule, only some three or four months to mature. In Lower Egypt the chief crop is "dura shami" (maize); in Upper Egypt, "dura beledi" (or millet, sorgum vulgare), maize, and "simsim," or sesame, etc. The cotton is by far the best-paying crop, and there is consequently a strong temptation to grow an increased area of it where soil, water, and climate will permit. It is also an exhausting crop, and at the same time a delicate crop, extremely liable to degenerate, to be chilled, and thereby checked and injured, by cold foggy nights, and to be attacked by fungoid and insect parasites. It is frequently found good practice not to grow it oftener than once in three years, to guard against the various dangers mentioned, though in some parts it is grown with comparative success every alternate year. Where it has been grown year after year on the same land for five or six years the results are not at all satisfactory.

Maize is an extremely important crop for the work animals, which are liable to become poor and weak when kept for a long period on "tibbin," or straw, which has been trodden and ground down in the process of thrashing out the grain to a condition resembling soft chaff. If the maize is planted at the proper season, viz, the 21st of July, so that it can secure the full benefit of the early "red water," the thinning, pulled as required, supply an abundance of green food for the work cattle during the busy "Nili" season. In Upper Egypt the thinnings from the millet crop (which much resembles maize in appearance during the early stages of its growth) are used for the same purpose, but as the young plant is extremely poisonous to cattle until it is about twenty days old, or until after the first watering, it is never used till this has been done. It seems to produce a deadly form of "hoven" in ruminating animals, from which horses and donkeys are exempted.

Birsem, or clover (*Trifolium Alexandrinum*), a large growthed plant with a white flower head, is the great winter forage crop of the country. It is, at the same time, the restoring crop, in virtue of the power it possesses in common with other leguminous crops, of making use of the free nitrogen of the air, and leaving in the soil a rich store of combined nitrogen in its abundant root residue. It is not only the safeguard of the Fellah against the worst form of deterioration of his land, but it is an ample means, in its green state, and also preserved as ensilage (for which it has been shown to be admirably suited), whereby the numbers of farm animals of all kinds, including dairy cattle, may be increased where desirable. * * *

* * * An attempt has been made to grow the potato for the early London market. At one place in Upper Egypt a crop of 10 tons per acre was secured, and a price of £7, or $34, per ton was got for the potatoes in Cairo. Some consignments realized £13, or $63.18, per ton in London, from which, however, about $23.30, per ton of expenses had to be deducted. The best land for the purpose, of many varieties of soil tried, proved to be the rich Nile mud of light character, which is covered by the Nile when in flood and annually manured by a silty deposit, the land which, before tobacco culture was prohibited, was used for the growth of that crop. * * *

The rotation of crops practiced by his excellency Reaz Pasha, the late prime minister, Mr. Wallace gives as a good example of what a rotation ought to be to yield the best returns:

(1) Cotton.

(2) "Birsem" (clover) or "full" (beans) to occupy the ground for five months. The land is afterwards exposed for five months without plowing or watering. This is probably to allow time for the root residue of the leguminous crop to decompose sufficiently to be of use to the next crop. If watered, the process of decay would probably be of a less suitable kind.

(3) Wheat, which takes five or six months. The land is left without crop for four months, or, if maize is not to be planted, for six months,

a matter which to a large extent depends upon the available supply of manure, as maize can not be successfully grown without it.

(4) "Dura" (maize) follows wheat, or the land is left fallow.

(5) "Birsem" is sown in the bottom of the dura ten to fifteen days before it is cut, when the land has become dry enough after the final watering, or it may be sown subsequent to the removal of the crop, or on empty land, after the fallow, about the 20th of September. In the matter of grains, the quality of Egyptian wheat as to gluten is somewhat low. Barley is of a better quality. Bread is the chief food of the "Fellahs;" also green vegetables and fruits, chiefly the date. In Lower Egypt maize is the chief grain in use for bread; in Upper Egypt it is millet. The wages of agricultural laborers are now 3½ piasters, or not quite 6 cents per day. The largest expenditure of hand labor in irrigation is caused by the level lift, or "shadief," by which water is lifted from the Nile or canals for summer crops. The chief tool is the "fas," a broad, short-handled hoe. The late Mr. Eugene Schuyler sent, as consul-general to Egypt, a valuable report to the State Department, in response to a circular prepared in 1889 by Irrigation Engineer R. J. Hinton, for the Senate special committee on irrigation and reclamation of arid lands, as a guide in the collection of information by the consular and diplomatic agents of the United States. Some of the interesting data furnished by Mr. Schuyler are summarized as follows:

Sedentary population, census 1882		6,302,336
Sedentary population to square mile		543
Land area:		
Irrigable, Upper Egypt	acres	2,400,000
Cultivated, Upper Egypt	do	2,215,000
Irrigable, Upper Fayoum Basin	do	280,000
Cultivated, Upper Fayoum Basin	do	220,000
Irrigable, Lower Egypt	do	4,000,000
Cultivated, Lower Egypt	do	2,740,000
Total:		
Irrigable	do	6,680,000
Cultivated	do	5,175,000

	Annual rainfall.	Evaporation.	
		Per day.	Per year.
	Inches.	*Inches.*	*Ft. In.*
Upper Egypt	1.056	0.197	71 9
Lower Egypt	8.365	0.079	28 0

	Ft.	In.
Slope of Upper Nile, per mile	4	68
Slope of Lower Nile, per mile	2	62

	Miles.
Mileage from source in Prince Albert Lake to Mediterranean	3,187½
From junction of Blue and White Niles at Khartoum	1,875
The Nile flood has a velocity at its beginning (per hour)	1⅓
The Nile flood has a velocity at its full (per hour)	3¾

Engineer Willcocks in his valuable work (Egyptian Irrigation, 1889) gives the discharges at Cairo and at the Barrage:

Locality.	Channel.	Season.	Discharge in cubic feet per 24 hours.		
			Maximum.	Minimum.	Mean.
Cairo	Main Nile	Summer	2, 189, 840, 000	883, 000, 000	1, 200, 880, 000
Do	do	Flood	36, 450, 240, 000	16. 423, 800, 000	24, 017, 600, 000
Do	do	Winter	7, 064, 000, 000	3, 178, 800, 000	4, 591, 600, 000
Barrage	Rosetta branch	Flood	19, 849, 840, 000	9, 536, 400, 000	13, 421, 600, 000
Do	Damietta branch	do	14, 304, 610, 596	5, 298, 000, 000	8, 476, 800, 000

Estimated mean daily discharge at Cairo, 8,830,000,000 in cubic feet.
Estimated mean annual discharge at Cairo at average of 3,349,660,000,000 in cubic feet.

In Upper Egypt there are 165 basins. They supply and cover 1,462,414 acres. There are also under summer cultivation 461,586 acres; by means of a siphon canal, 291,000 acres: total, 2,216,990 acres.

The system in vogue is a river, with transverse and parallel dikes. There are 21 basin systems, and the water is usually first let into the upper one, then passed into the others, and what is drained back from the lower basin into the river.

For ten years past the average flood variations between highest and lowest gauge has been 9 feet 1 inch. The annual Egyptian Nile rise begins at the end of September. The White Nile reaches its maximum in August. The Blue Nile begins in April its rise on the Abyssinian plateaus. At Assoor, the beginning of Egypt, the maximum flood occurs between August 15 and September 30. It is proposed by the English engineers to construct high-line canals and fill all the basins simultaneously. The total ordinary expenditures for irrigation were given for 1890 at $2,560,000. Mr. Schuyler wrote that—

> There are, however, also extraordinary expenses. In 1885 a decree allowed $5,000,000 to be spent for the improvement of the irrigation works. Of this there had been spent on December 31, 1888, the sum of $4,233,075. There will be allotted from a new loan now being negotiated the further sum of $4,550,000 for the same purpose.

The aims of the Anglo-Indian engineers now and for six years past in charge of Egyptian irrigation works, are thus epitomized by Mr. Willcock:

> (1) The strengthening and securing of the barrages so as to insure a constant high-water level during summer, and not only utilize the whole summer supply of the Nile, but do away with a great part of the heavy silt clearances.
>
> (2) The construction of escapes and supplementary flood canals, so as to irrigate during summer from the summer canals, and during high Nile from the summer canals in their lower reaches, and supplementary flood canals in the upper reaches of the summer canals, and thus reduce silt deposits.
>
> (3) Having reduced silt deposits to a manageable amount, to substitute dredging and contract work for the *corvée.*
>
> (4) The obtaining of flood supplies as early as possible into the flood canals.
>
> (5) The reduction of regulation of the supplies entering the summer canals during flood so as to save the lowlands from inundation.
>
> (6) The improvement of the lowlands themselves by drainage and basin irrigation.
>
> (7) The improvement of the navigation.

The land tenure and water supply practices in Egypt are a very uncertain quantity for the poor man. Lands are leased or rented, are tithe and tributary lands, "nulk" or freehold. The latter is modern in origin. The state is considered, as in India, the real proprietor. The management of irrigation has always been in the hands of the rulers, whoever they may be. Mr. Schuyler says:

> According to the existing laws remission of revenue is granted on land incapable of being sown with the winter crops, although flood crops irrigated by lift are ex-

pected to pay the full taxes, but no provision is made for crops destroyed by floods during the inundations, or by drought in summer. Owing to the fact that there is plenty of water when the crops are sown, they are often sown to excess, and as the summer supply of the Nile only suffices for about one-third of the area in lower Egypt in May and June there are very often failures of harvest. All such cases are now decided by the native court and the mixed tribunals on the basis of certain articles in their codes, but these are very insufficient.

Mr. Willcock says:

> This not in a country where the Government sells the water, but where the Government performs functions that the atmosphere does in other countries. However, things have become so bad now that something must be done. Previous to 1882 the mudirs or civil governors protected the poor as a rule from Jews and Christians, while the State was strong enough to hold its own. Now the tribunals dominate the State, and are unable to help the poor.

The water-lifting practice is one of the most important in Egypt. It consumes a great proportion of the agricultural labor, all the more so because rude and simple. Lifts less than 40 inches are made by means of the "nattal," a closely woven palm basket with ropes on either side, held by two who stand or sit near the water's edge. They swing this in such a way as to fill it with water and throw it into the mouth of a small ditch, which carries it over the fields. By this process two men can raise from 140 to 175 cubic feet of water per hour. This has the advantage of being easy, inexpensive, and applicable anywhere in proper conditions. When it is necessary to raise the water more than 40 inches this becomes fatiguing, and the "shadoof" is resorted to.

The old well sweep used in this country illustrates this system. The water is taken from small wells dug into Nile banks and filled by the river flow. The work is slow. A man averages only about 10 baskets or 22 gallons a minute, that is, 211.90 cubic feet per hour. The relays of men are changed every two hours. It is estimated that when the bank is sufficiently low to allow of "shadoofs" two men will water an acre and a quarter per day.

Water wheels are in common use, principally the "sakieh" or Persian wheel. Whoever has visited Boise Idaho, has seen such wheels, improved somewhat as to buckets, etc., in operation along the streets. On the Snake River, also, such wheels, very much enlarged, are in general use. One of the Egyptian "sakieh" will irrigate from 5 to 6 acres. The "sakieh" consists simply of a vertical wheel, an endless chain of small earthen pots, placed at about a foot from each other, which descends into a rude well on the bank of the Nile, thus bringing up the water and pouring it out into a trough leading into a canal. This vertical wheel is turned by another horizontal wheel applied to it by a rude system of uneven cogs, itself turned by a cow or a buffalo harnessed to the end of a long lever. The "sakiehs" are sometimes used in wells in the middle of fields, where such exist, and their existence is known at a long distance by the groaning sound produced by the creaking cogs.

There are estimated to be 28,000 "sakiehs" in the delta or Lower Egypt, where the water has to be lifted from the canals for all summer irrigation. The total area therein is stated at 1,235,500 acres.

IRRIGATION IN ASIA.

THE TURKISH PROVINCES.

Irrigation in the Turkish provinces of the Mediterranean, though necessary for the major cultivation, is still carried on under the most primitive forms and conditions. As will be seen from the annexed presentation of the Ottoman code, the control of the water is maintained in the community. Ancient and oriental communities, practicing irrigation, have had the water supply therefor under public control. Where great works were constructed in ancient times they were so made at the expense of the sovereign or State. As in Egypt down to a very recent period, the "*corvée*" or enforced labor prevailed in all irrigation, road making, or other public works. Even in portions of India the system still prevails under modified forms. Assyria, Babylon, the ancient kingdoms of the Levant, those of North Africa—as Carthage *et al.*—Persia, Ceylon, and the Brahmin, and the Mahommedan and other more ancient rulers of Hindostan have all constructed and possessed great systems of storage and distribution, the engineering skill displayed in which is still the admiration of those who have studied them. Yet the chief results of irrigation cultivation have in all oriental countries been obtained by the small cultivators and the petty and individualized irrigations. These have gone on holding their ground to a large degree under systems of community regulation, and maintaininga considerable amount ot agricultural activity, in spite of the historical fact that the great State works, often racial, dynastic, and always imperial in character and extent, have been destroyed during the progress of the tremendous wars, which in the ancient world have destroyed empire after empire, and communities, cities, towns, villages, with all their works, agricultural life, and other industries. Yet the small irrigation has held its place and is found everywhere, even as in Thibet and on the Pamar, at an elevation 12,000 feet above sea level the pivotal fact on which a working life has been sustained, and upon which, with new forces, as in British India and in Russian Central Asia, larger and more sustained development in the modern sense, has been or is being organized into existence. China and Japan are remarkable examples of what can be sustained in the way of industrial civilization by means of the individual farmer, working under simple community rights as to water and its use in cultivation. China and Japan have not in use a single great work, outside the great canal of China, for irrigation supply and distribution; yet the two empires carry on under their primitive but minutely-careful mode of irrigation an agriculture by which at least 300,000,000 persons are directly sustained. In British India at least one-third of the vast population are equally fed from small irrigations, the water for which is obtained from village wells and tanks or small ditches, that have been in use (or are modeled upon those that were) for many centuries. In all cases there are written or unwritten codes, customs and regulations, which recognize the public nature of water and provide for the local or community control thereof. Taking the populations of other European dependencies, of Persia, Afghanistan, Thibet, Corea, and the native States generally, it will be found that at least 450,000,000 Asiatic persons are dependent for food upon the small irrigations under review.

The Ottoman code or law of water rights, usages, and proprietorship is an excellent example of the principles underlying the community water control system of Asiatic countries. It has already been published in a consular report, but is inserted here as an illustration of an historical condition:

> Water, herbs, and fire are things outside commerce; all men enjoy them in common.
>
> Water running under ground is the property of no one in particular.
>
> Wells not sunk by anyone in particular, and which are used by the public in common, are common property.
>
> Seas and great lakes are common property.
>
> Streams of the public domains, that is to say, those which do not specially belong to anyone, are those whose bed is not the property of a number of persons; such streams are in common, as for example, the Nile, the Euphrates, the Danube, etc.
>
> Private streams, *i. e.*, those whose beds traverse the lands the property of private persons, are of two kinds:
>
> 1. Those waters are subdivided among coproprietors, but which do not empty or exhaust themselves completely into the lands of the latter, and which run afterwards into public rivers; such water courses are also designated public because part of them is public domain; the right of preëmption is not applicable to these water courses.
>
> 2. Private water courses which run within the limits of the property of a given number of persons, and whose water is exhausted and disappears upon such property without reappearing to form another confluent; preëmption rights are only applicable to such water courses.
>
> Alluvium deposited by a stream on the land of a private individual becomes that person's property; no one else can lay claim to proprietary rights thereto.
>
> Herbs of natural (wild) growth upon lands the property of no one in particular are held in common, the same with herbs that grow upon private property unknown to the owner; but if the latter waters his land or incloses it with a view to prepare it for cultivation, then the herbs growing thereon become his property; no one else can appropriate them, and he who gathers them is held responsible therefor.
>
> By herbs are meant such plants as are not artificially watered; mushrooms, for instance, are included therein, but trees are not.
>
> Trees of natural (wild) growth upon mountains, which have no owners (djibali monbaha), are held in common.
>
> Trees of natural (wild) growth upon the property of anyone belong to the owner of such property; nobody can cut them down without his authorization. He who grafts a tree becomes the proprietor of the shoots and fruit thereof.
>
> If anybody occupies a thing now common he becomes the exclusive proprietor thereof.
>
> Examples: The water which a person draws from a stream with a receptacle becomes his undisputed property, and if a third person consumes it without the owner's permission he is held liable therefor. The occupation of a thing must show intent; consequently, he who has placed a receptacle with the intention of collecting rain water becomes the owner of such water. The same with water accumulated in a basin or cistern; but the rain water found in a receptacle not expressly placed for such a purpose is not the property of the owner of the receptacle, and other persons may appropriate such water.
>
> It is necessary in the occupation of water that it does not run continually; so, for instance, well water, which filters through, is in common. He who consumes the water thus obtained by filtration, even without the proprietor's consent, is not held liable for damages. Again, water is not considered as having been appropriated where as much enters a basin on one side as escapes on the other.
>
> Everyone may enjoy a thing held in common on condition that such enjoyment causes injury to no one.
>
> One can prevent a person from occupying or appropriating such a thing.
>
> [The contestations relative to water courses for drinking or irrigating purposes, and the customs and usages existing from antiquity are only to be taken into consideration.]
>
> Everybody can use the waters of public streams for his lands, and may for this purpose, or for the purpose of constructing a mill, dig canals and ditches or trenches on condition, however, of doing no injury to anyone. Works which cause an inundation, those which completely exhaust a stream or which prevent boats (barges) from floating, are to be interdicted.
>
> Man and beast may drink of the waters not the individual property of any-

one. The right to use water for irrigation and for the consumption of animals ("chirb") of water courses not public property belongs to the owners of these streams (courses); any other person, however, may drink therefrom. Thus no other person than the owner can serve himself of the waters belonging to a community or of a ditch, trench, or well, for irrigating purposes, but he may drink therefrom and even water his animals, provided the number of these be not so large as to damage the water course, the canal, ditch, trench, or conduit; he can likewise draw water therefrom with a pitcher or a pail and carry it to his house or garden.

Those who possess a brook, stream, basin, or well upon their lands whose waters are renewed by nature may prevent anyone who wants to drink therefrom from entering their property; but if there exists no other water in common in the neighborhood the owners are obliged to either offer the use of their water or allow their lands to be penetrated; and in case they fail to offer their water those who wish to drink may enter the property, provided no harm is done thereto by damaging, for example, the edge of the wells or the water conduits.

One of the coproprietors of a common water course can not, without the permission of the others, cut a channel, ditch, trench, or gutter. He can not change his "turn" or share of the enjoyment of the water long established, nor cede such right to a landed proprietor who has no right to the waters of such a river for irrigating his field or watering his cattle.

The authorization to perform these acts given by the other coproprietors could be revoked by these latter or by their heirs.

In all contestations touching drinking water or water for irrigating purposes the rules, regulations, and usages established *ab antiquo* are to be enforced.

The waters of rivers, streams, springs, and other water courses passing through the lands of a village or a city are the property of the community, and must be distributed, as has been the ancient practice, in such a manner as to secure a supply to each landed proprietor during certain hours either weekly or fortnightly. Every owner of land knows the exact time and quantity of water to which he is entitled, and in almost every village there is a civil officer who is charged with the duty of looking after the proper allotment and distribution of the water among all the inhabitants. Time is usually measured by hourglasses.

In Asia Minor, Syria, and Palestine, the sources of supply for irrigation are the small streams, wells, and pools, and the modes of using and distributing are of the simplest character. Olive trees, for example, are seldom watered after the period of growth before bearing. The fig tree is irrigated generally for a limited period each season, by means of the water bag carried by men to each tree and applied directly to the roots. Shallow wells are numerous, and their water is lifted generally by means of a wheel, the flanges of which are also water buckets. A large buffalo skin is made into a bag by cords at the corners, let down into a well, and then drawn up filled with water, which is emptied into a conduit. The power used is generally animal—oxen, asses, or camels. The general plan used is known as the "Na'hura" wheel, clumsy in construction, but raising a considerable quantity of water. It consists of a clumsy cogwheel fitted to an upright post and made to revolve horizontally by an animal attached to the sweep; this turns a similar one perpendicularly placed at the end of a heavy beam which has a large wide drum built over it, directly over the mouth of the well. Over this drum revolve two rough hawsers or thick ropes, often made of myrtle twigs and branches twisted together, and upon them are fastened small earthen jars or wooden buckets. One side descends while the other rises, carrying the small buckets with them; those descending are empty, while the ascending ones are full; and as they pass over the top they discharge into a trough, which conveys the water to the cistern. The length of the hawsers and number of buckets depend upon the profundity of the well; for the buckets are fastened to the hawsers about 2 feet apart. The wells are of different depths, but generally average from 10 to 15 feet. It is claimed that with good animal power a bucket containing about 2 gallons of water can be raised every second.

PALESTINE AND SYRIA.

These still remain irrigation lands, though its extent is now very restricted. The management of the water is crude and primitive in character. Mr. Henry Gilman, United States consul at Jerusalem,* says:

> Small fields, gardens, or patches of ground are here and there cultivated in the neighborhood of some stream having its source in one of the perennial springs of the region. From such a spring the water is conveyed in shallow drains or ditches to wherever required, and is carried through the fields or gardens by still smaller channels, the water being shut off or let on simply by the action of the foot, opening the tray inlet, or blocking it up with a few pebbles or masses of clay, as may be desired.

In the scattered and small areas in which cultivation by irrigation is practiced, the Bedouins of Palestine follow the simplest methods. Mr. Schumaker, United States consular agent, says:

> In the early morning or shortly before sunset young Bedouins, in a seminude state, may be seen roughly constructing from stones and earth a temporary dam to obstruct the waters of a stream or wâdi (valley), while others provided with broad hoes dig little ditches through which they lead the overflowing waters, to be distributed over the parcels it is intended to irrigate, allowing the water free course in the lower lying lands, thus inundating or rather completely setting them under water. These manipulations are of daily repetition; the dams have to be regularly rebuilt, for the pressure of the water causes their daily destruction, and it is interesting to watch with what assiduity and perseverance these Bedouins are continually remaking and renewing the little ditches and canals, which need their unremitting attention.

At Jaffa and in its neighborhood there are about 3,000 acres of oranges, olives, and other fruits, with garden vegetables, under cultivation by irrigation. The value of such exports per annum is about $300,000 a year. The water is drawn from shallow wells, chiefly by the "vajara," a simple water wheel, of which some 700 are in use. The irrigation season, from May to November, is one hundred and sixty days, and the cost of water will be from 20 to 25 cents per acre; that for the dry period will be at least $33 per acre. The net yield per acre will not be less than $150, the exports being valued at $120 per acre.

In Syria itself works for the utilization of the underflow are quite numerous. They are usually placed on lands lying along the foot of a mountain, from which rivers, springs, streams, or other water courses flow, and which by reason of their gentle slope adapt themselves for irrigating purposes.

At Beirut the irrigation area extends 5 miles in one direction and some 10 in another. Mulberry trees are the most abundant product. In Tripoli the chief orchards are of oranges. The area covers 5 acres square. They are supplied with water from the Lebanon range. There are considerable areas under cultivation by irrigation in northern Syria. Canals or ditches are expressly dug for this purpose where they do not already exist or where the water does not run of itself. The canals are usually old and are not kept in good repair. Springs are carried into cisterns or tanks built of masonry well cemented, which are usually emptied each day. Large reservoirs are unknown, and the maxim among the natives in force is "that irrigation is only profitable where the water runs unaided by man." Their ancestors were of a different opinion, judging from the numerous works left by them scattered broadcast over the land. In modern irrigation and waterworks the Beirut waterworks take the first rank. They are the property of an English stock company, which furnishes an excellent quality of drinking water at fixed rates, as well as a needful supply for irrigation purposes at reasonable charges.

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*Special Consular Report on Canals and Irrigation, 1891, p. 342.

Progress is made in three directions. Pulsometer pumps of considerable power have been introduced, and in one instance proved entirely successful, though the water is raised 130 feet. American wind motors are also slowly coming into use. The Mount Lebanon areas are exceptionally well cultivated. Mr. Edward Bissinger, United States consul in Beirut, says:

> Irrigation, as has already been shown, is regulated entirely by usage and well-established rules, and every parcel of land has a right to the use of water for certain well fixed length of time; for instance, a small proprietor near Beirut has 5 acres of land; every Friday he can take as much water during six hours as he may need to thoroughly saturate his land; if he fails to take advantage of his privilege he simply forfeits it without being indemnified therefor. Where water is scarce, as in many places in the mountains, it is often divided into hours and even fractions of hours, and good care is taken that no one receives or takes more than his allotted share. The sole owner of a spring, a rare occurrence, however, may of course use the water thereof at his own pleasure.
>
> It is worthy of remark that in Mount Lebanon the waters of every spring, no matter how limited its capacity, is caught up into cisterns of good solid masonry and is utilized for irrigating and domestic purposes, and no matter how steep the mountain sides or how poor the soil, the smallest available tillable space is planted with onions, vegetable marrow, or egg plant, and three and sometimes even four crops are thus produced each year.

Projects and plans of a considerable character are under way or in consideration in Syria and Palestine, and a few years will undoubtedly see a large addition to the cultivated area of both these historic regions.

In Syria there are a number of works of great antiquity; some are in ruins, but others still remain in use. Near Beirut are two aqueducts, built upon arches or cut partly through solid rock. The works at Damascus, Tripoli, Horus, Hamath, Tyre (Solomon's Pools), and other important points, are of great antiquity. The conduits and aqueducts are of stone masonry, earthen pipes, or hollowed out of stones in place or artificially arranged. Beirut is furnished with modern works, constructed by an English company. Reservoirs are unknown. In the valley of the Euphrates and on the Mesopotamia plains there are many ancient works of great extent now largely disused, but which could be availed of if the channels were cleared out and repaired. In Persia, Afghanistan, Turkestan, there is a system of underground conduits called "karnaks," by which phreatic water is conveyed long distances and distributed to fields below the point of debouchement. These "karnaks" are made by digging well holes to the gravel, sand, or boulder stratum in which the drainage water is gathered. They are made a short way apart, beginning generally in some foothill section. When the bottom is reached a conduit or small tunnel is hollowed or dug out from each well. In this wise the water of the saturated stratum is gathered into a stream which flows under ground, until by gravity the water therein flows over the fields below the mouth of the "karnak." The wells or openings are often used as watering places for stock, as well as for domestic purposes. There are many hundred miles of these rude conduits in Persia. They are also in Cashmere, Afghanistan, and other points of Central Asia, where the mountainous topography gives promise of a large supply of phreatic water. English travelers have called attention to the danger attending such conduits in the probable desiccation of areas lying above the route of the conduits. It has been observed by such travelers that grass and other forage perishes along the line of the "karnaks." This is a point worthy of consideration.

Something similar to these devices is described by Mr. N. A. Nahikon, who writes as follows:

> The most extensive system in Armenia, is by wells dug in the following way: First a man will take the level of his land, then going up toward the base of the mountain he will have a well dug, generally from 80 to 100 feet deep, which will be a few feet above the level of his land (the bottom of his well I mean); then they dig three other wells between these two points, the depth of the wells diminishing, of course, as they approach the farm. They dig a tunnel through the bottom of all the wells high enough for a man to walk through. This precaution is taken so that, in case there be a cave in of earth, they can open one of the wells (which has simply been roofed over), and a man is lowered down to see what is the matter. The water will flow through this tunnel until it comes to the surface by gravity at the desired place. Here they make a kind of reservoir 40 by 25 feet in size and about 3 or 4 feet deep, taking care that the bottom be not on sandy soil; and then to stop the evaporation of water from the said reservoir, they plant all around it mulberry trees, which, having thick foliage, will almost entirely hide the water from the sun's rays. These reservoirs are generally owned by several persons, and the measure of distribution is by the reservoirful per fortnight. Many persons may not own either any land or water, but may have the trees as property. These waters also during the winter go to waste. In the summer they are awfully cold. Really I know many of them that are too cold to wash hands in or drink at the point where they just come from the ground.

There is not a single perennial stream of water in or near the city of Jerusalem, and only one in its immediate environs. There is a small stream which for a few weeks in winter flows down the Kedron Valley half a mile below the city; there is another ephemeral fountain which gushes forth a few weeks in the winter. Siloam is the only perennial stream about Jerusalem, if indeed that can be called a stream, which is intermittent.

The population of Jerusalem has always been largely and almost entirely dependent on wells of living water.

The winter rain was to the Hebrews what the Nile was to the Egyptians, and every means was adopted to economize the scanty supply. At a distance of 7 miles from the city there were extensive tanks and wells constructed, undoubtedly of the greatest antiquity, the intention of which was to collect water, to be conveyed by conduits carried upon and beneath the surface, and on a due level around the slopes of the country, a distance in its windings of not less than 12 miles. Two of these aqueducts conveyed the water; the one directly to the city near the Jaffa gate, and the other in a circuit around Zion on the southern side to the temple. All writers on Jerusalem who have investigated the water supply attest the fact that, notwithstanding the aridity of the surrounding country, the inhabitants of the city have always had water enough and to spare.

Aristeas, an eye witness, says:

> There is a continual supply of water as if there had sprung up an abundant fountain underneath, and there were wonderful and inexpressible receptacles under ground, each one of which had divers pipes by which water came in on every side.
>
> All these were of lead under ground, and much earth was laid upon them, and there were many vents in the pavements not to be seen at all by those who served, so that in a trice all the blood of the sacrifices could be washed away, though it were never so much.

The city of Jerusalem is indebted to Sultan Mahomed for its present supply of fresh water, as the Mahommedans even more than the Jews require an abundant supply of fresh water for their religious observances.

The pool constructed by Solomon, called the "King's Pool," 8 miles from the city—

> consists of three enormous reservoirs, partly cut in the rock, partly built of massive marble masonry. Their dimensions are as follows: The upper pool, 380 feet long; breadth at east end, 236 feet; at west end, 229 feet; depth at west end, 25 feet.

> The middle pool, which is distant from the upper pool 160 feet, is 248 feet long; it is at east end 250 feet broad and at west end 160 feet, while the depth at east end is 39 feet. The lower pool, 248 feet eastward of the middle pool, has a length of 582 feet; a breadth at east end of 207 feet, and at west end of 148 feet, and a depth at east end of 50 feet. Each pool overflows successively, by regulated sluices, into the next below it, in the order given, the last pool emptying its superabundant water into the valley. The source of the water supply is the Sealed Fountain of Solomon, at the foot of a hill, a short distance west of the Upper Pool. This fountain is always kept locked; hence the name. A flight of twenty steps descends from an arched doorway into an underground vaulted chamber, where four streams of pure and cool water converge.

A small acreage is irrigated from these pools and from that of Siloam. There is a copious spring in use for the valley and village of Urtas. Consul Gilman says:

> The distribution of the water is regulated by the old custom of system of "fassels," a night and a day forming a "fassel." Each family owning land there know, from time immemorial, its respective rights and share in the "fassel" of water. Some have an entire "fassel," and again the same is divided among the different members of a family, to irrigate their respective shares of land. The water is carried from one plat to another by drains in the usual simple manner already described. The Europeans who own land there have made, however, a cemented conduit to convey their share of water into their ground. No statistics are obtainable, none ever having been kept, as to the duty of water per acre. No special rent or fee is paid for the water used, nor are there any charges on the land in connection therewith, the only payments made being the usual government taxes—the "werke" (land taxes) and "ushur" (titles). Solomon's Pools, the Sealed Fountain, and the aqueduct are public property, and are under the control of the Turkish Government.

The temperature of the water at Jerusalem is about an average of 65 degrees. The largest tank or cistern remaining is 376 feet in circuit, is 42 feet deep, and has a capacity of 2,000,000 gallons.

These meager statistics of the water supply of Jerusalem have been given because the city is better known than any other ancient capital, and from the fact that its surrounding desolation and aridity exceeds any part of our Western domain. Our frontiersmen can reasonably take courage by the comparison.

CHINA.

All irrigation in the Empire is conducted practically on a mutual or coöperative plan. The sources of water supply are generally the tributaries of large streams, the latter being made useful for navigation with irrigation as an incidental service. The most minute care is taken to preserve every source of water or other liquid for use in cultivation. In southern and central China it is estimated that 1 acre of cultivated land will support from three to five persons. Rice and vegetables are the chief crops. Wheat, millet, and barley are raised in the northern and far inland provinces. Irrigation processes in southern China are described by Consul Seymour as follows:

> Return rows of growing vegetables, trenches filled with water obtained from the creeks, brooks, or pools, are kept; and once or twice a day the water is scooped from these trenches upon the raised ground, in which the roots have great depth of loose and moist soil to promote growth. When these trenches of water are not available, owing to scarcity of water, or to porous land, the men and women carry, suspended from a yoke across their shoulders, two large buckets with long spouts, and sprinkle the rows of vegetables copiously. Sometimes the water for this purpose is carried in buckets a considerable distance. For the irrigation of rice lands, which have to be submerged, the lands are divided into small patches at large levees, so that the appearance is that of a beautiful system of terraces, near a bountiful supply of water, which is raised to the upper level of chain-pump and tread-mill process with cooly power. From the upper to the lower levees the water decends so gradually as to avoid washing away the substance or fertility of upper to lower lands.

In Ningpo, Fo-Kien, and Shanghai the modes of irrigation are generally from small ditches, taken from streams or large canals. At

Ningpo the ditches are mainly fed by phreatic waters supplied from springs, which come to the surface in the bordering hills of the valley. The river water being brackish is never used. The supply canals are numerous, from 2 to 3 miles in length, and supplying the shallow laterals, which are dug at right angles, from 200 to 400 feet apart and 10 to 30 feet wide, supplying all the small fields and tiny gardens of the Chinese farmers. In the province of Fo-Kien, as the rainfall is equally distributed and quite heavy, irrigation has become an additional security rather than a primary necessity. There are no storage dams, though the country is well adapted to their construction. Consul Campbell, of Fuchan, says:

> The water used for irrigation is drawn up from the ponds and water courses by an endless chain or rather an endless rope pump, which is worked by one man or sometimes two men by treading upon a wheel made with a number of radiating arms which causes the wheel to turn upon its axis. A horizontal pole about 5 feet above the shaft is made fast, and the men support themselves by leaning upon this pole by treading the wheel. One end of the box through which the chain draws the buckets is placed in the water at an angle of about 45 degrees with the pond, river, or canal from whence the water is drawn into the field. The box is open at both ends and is made strong and light. The whole apparatus is easily carried by one man on his shoulders. The faster the man treads the wheel the more water is pumped, and the machine is kept going night and day when water is needed for irrigation. The pump is run very much on the principle of the treadmill so far as the motor power goes, and the water is carried up with the buckets something like wheat is raised in an elevator. * * *
>
> Water is conducted into the fields, which are usually marked off into small compartments according to the number of proprietors by earth embankments, the water filling one after another until all are covered. Everything is carried by human beings on their backs. The vegetable garden, flowers, and small plants are watered by water carried on the backs of the laboring people—men, women, and children.

There are no written codes or laws; custom, handed down from immemorial time, rules everything. According to the latest idea of the ethnologists and historical students, the Chinese, in irrigation and other things, derive their methods from Assyria and Babylon, as they are considered to be descended from the most ancient Turanian stock, whose existence on the plains of Mesopotamia is regarded as indisputable. The processes indicated are general throughout China, while on all sides and by every ingenious primitive process that can be devised the most economy in storage and the largest duty of water in distribution is daily obtained. There is a recent increase of interest arising, owing, probably, to the fact that so many Chinamen have seen irrigation of late years in other countries and under different conditions. Quite recently the office of irrigation inquiry has received a request from an English engineer in the service of the Imperial Government and stationed in Yunnan, the province lying next to Annam and Burmah, asking for information relative to artesian waters and wells, he being about to commence boring experiments.

Recent speculation on the racial origin of the Chinese, attributing their civilization and policy to a migration from Babylonia and Assyria, seems to receive a contradiction in the nature of the agriculture, canal, and irrigation works. The latter, at least, were of a much larger and more important character in the valleys and plains of the Euphrates than is anywhere to be seen in China. The navigable canals in the provinces accessible to commercial and other outside intercourse are all used as sources of supply for the irrigation ditches and laterals. United States Consul Pettus, of Ningpo,* says:

> At Hangchow the canals of this district connect with the Grand Canal, which leads as far as Peking. Almost every farm in this district has its canals for transportation and irrigation.

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* Special report on "Canals and irrigation," State Department, 1891, pp. 64, 65.

> Branch canals are excavated from the main canals at short distances, from 100 to 300 yards. These canals run at right angles from the main arteries, so that all the farms and gardens can be irrigated, which is done by wooden chain pumps made to reach the water from the bank. They are worked by hand or ox. So all farms in the valley are irrigated, always insuring a good crop of rice.

The lifting of water in China, as seen in the maritime provinces, is thus described:

> From these (the main channels), where the tides do not rise sufficiently high for irrigation, water is raised artificially by simple but rude machinery. This consists of a main cog wheel, worked by oxen, which turns a roller at the upper end of the trough; at the lower end of which, immersed in the canal, there is another roller, and over these an endless series of wooden boxes revolve. The boxes or boards fitting the trough elevate the water and pour it into the fields, over which it is distributed by open drains. The whole machine is readily moved from place to place, and the trough can be arranged at any angle to suit the inclination of the bank.

In other methods of lifting water the ingenuity of the Chinese is strikingly apparent. Of the chain pump there are three adaptations of the same principle. One is operated by animal power, the two others by man power. The first is provided with a mechanism precisely the same, to all intents and purposes, as the horse power suited to the older styles of thrashing machines. This is probably as old as husbandry itself in China. It shows that they understood that power and speed vary inversely, or that power or time is gained according as the moving force is applied near or remote from the axis of a wheel. The chain pump attached consists of a hollow trunk formed of boards, having at each end a short axle provided with cogs, over which an endless chain, having a series of buckets upon it, passes. The trough is placed in an inclined position, with one end in the water to be raised. The upper axle being put in motion by its connection with the power machine (which is placed on the bank of the canal, river, or pond, and operated by a buffalo yoked thereto), causes the endless chain to rotate. The buckets retain the water and raise it to the end of the trough, from whence it flows onto the field. The second description of chain-pump is worked by men, operating upon a description of treadmill with the feet. The upper axle of the endless chain of pumps is extended to a long shaft on either side of the trunk, and provided with short, radiating arms, serving as levers for the action of the feet. A rotary motion is thus communicated to the shaft and the endless chain of buckets. The other description is worked by a crank in the end of the upper axle of the chain pump by hand power.

JAPAN.

In the Island of Lewchew, belonging to Japan, irrigation is so carefully handled as to demand special mention. It is still characteristic of the methods in use. The streams are small and short, brief in their course, and are all appropriated to irrigation. In their management of water the Japanese islanders are always seeking to secure "the retention of water or moisture, and the avoidance of surface washing." In both cases they have succeeded. Dr. Green, U. S. Navy, who accompanied Commodore Perry's expedition to Japan, says:

> Wherever a stream is found, whether large or small, also whenever springs issue from the sides of hills (if not excessively steep), the system of grading begins. If the ravine be very narrow, the sides near the bottom are cut down perpendicularly for several feet, and the bottom leveled from side to side, the level becoming wider as the sides recede from each other. It is formed into steps by slight, narrow banks running across, capped with grass. The height of these embankments is always small, rendering the length of the step or plot longer or shorter as the descent of the valley is greater or smaller. A plot of only 6 feet square is not neglected

or despised. Where there is not a ravine, but an open, spreading valley, the sides are not thus cut, but the leveling is effected by running the embankments across it in a curved line corresponding with the ground, the arch being always up the valley. If the stream be large enough to furnish side supplies, open ditches or conduits are carried along the sides, and the water is allowed to descend from plot to plot, the embankments of which are adapted to the surface, being arched outward, or from the side, where an elevation projects into the valley; and inward, or toward the side, where a depression occurs on its face. By this means no dams, as such, are made (liable to be washed away); but gentle descents of a foot or so are made from step to step, without any risk of injury, and requiring only the slightest restraints or banks. These are all covered with grass, and serve as divisions of property and also as pathways. By this simple arrangement great floods may be diffused over level land, and fall from grade to grade so gently as to pass off without detriment to the feeble embankments, and without injury to the soil by washings. This is the grading for irrigated lands. That for rolling lands is not unlike it, but is not brought to such exactness, as a perfect water level is not so much needed. Hillsides are thus cut into terraces, varying in width from a few feet to many yards; and also in length, according to the inclination or shape of the land. The same small margin of grass is found here on the embankments, which are from 1 to several feet in depth ere another terrace is reached. In this way, when the hills are conical and the terraces are arched outward, they look like giant circular steps from base to summit; and where a valley is regular and steep, they are arched inward, and appear as the steps of an immense amphitheater. The terraces are subdivided as the irrigated plots are, or by stones, or slight mounds of earth grassed over as division marks. They are bedded up gently towards the center, and all around the margin there is a slight depression or furrow by which superfluous rain water is carried to some point to be let down to the next level. But before allowing it to escape, it has to pass over a hole or reservoir in the ground, generally partially filled with vines and haulm. Any alluvial soil is thus arrested as sediment to assist in making compost or manure, the water alone escaping. Before escaping finally, however, into a stream or river, it has to traverse a much larger reservoir for the same purpose.

Rice is grown only on irrigated land, which is first saturated, the soil being deeply upturned by the hoe. Where flooded a gang of 2 to 4 men enter each plot of land. Each one of them hoes a row across it, each row about a foot wide, in form like a plow furrow. The plants are then set out, having been first seeded in separate plots. The work is swiftly done, the men moving along, dragging the young plants after them, at intervals of 6 or 8 inches, in the soft earth under water. In front is a sheet of water, behind the laborers is a field of rice, growing in regular rows. Apparently no culture besides digging is required. When dead ripe the rice is harvested. Two crops are grown annually, besides a winter one of sweet potatoes. The uplands are watered only by the rains, skillfully conserved by the system of grading and ditching already described. The cultivation is as minute and careful as in the rice fields.

The agriculture of Japan is carried on in a similar manner as in the island of Lewchew. As to rice, the great staple of Japan, it is sown broadcast in seed beds, which are covered by shallow water, and the seed may be seen lying upon the earth through this water. When drawn the plants are floated by the drains to the place of planting. The ditches used are small, and in general the water or manurial fluids are carried to the plants by laborers. There are about 12,500,000 acres, nearly two-thirds of which are under irrigation, while the population is over 41,000,000. There is no general code of water regulation; as in China, local customs and coöperation control. Peasant proprietorship of land is the rule in Japan.

SIAM.

Consul-General Jacob T. Child gives in the State Department Report on Canals and Irrigation (p. 369) the following brief account of irrigation for rice in Siam:

About one-half of the country is under cultivation, and of this portion fully four-fifths is under irrigation. Rice is the staple, consisting of two kinds, na suan, or garden rice, which is transplanted, and the second grade, na muang, or field rice. It is estimated that about 10,143,800 piculs (1 picul = 133⅓ pounds) are annually grown in Siam.

Water is supplied to the fields by means of canals, which branch out from the rivers in all directions.

The water is conducted into the fields by small canals and ditches. The fields are divided off into ris, containing about one-third of an acre. Around the four sides of each ri an embankment is thrown up, about 2 feet in height, with an inlet, to allow the water to each ri, in turn, until the whole number of ris is full. There are no published works upon irrigation.

This system is governed by laws and customs. There is no duty upon the water, but if the land is Government property there is an annual rental in the form of a tax of 28 cents per ri, which includes the use of the water. The large canals are built at the expense of the General Government, but the small canals leading to the fields must be dug by the individual.

The climate is tropical, with a wet and dry season. The average annual rainfall is 67.04 inches.

The system of irrigation has been in use from time immemorial, and is maintained partly by public and partly by private expense.

THE SANDWICH ISLANDS.

The Hawaiian Islands are largely dependent upon irrigation for agricultural security, and the works, therefore, are generally of the most modern description, and are often, too, quite extensive in character. Sugar has increased its yield under irrigation from 2 to 4 tons per acre. There are about 90,000 acres under cane; 7,000 or so under rice; of bananas about 5,000 acres. Half the cane and all the rice fields are irrigated. The water supply is derived from mountain streams, storage reservoirs thereon, springs, and artesian wells. The distribution is generally by means of pipes, which are usually of wrought and cast iron. There are some extensive open ditches from 5 to 40 miles in length. No water code exists; the ownership is by lease, public and private, and the cost (by pumping) is $3 per month, or $45 per acre each season. The Kanakas have always used irrigation ditches for the purpose of cultivating "*kala*," from which their chief food, "*poi*," is made. Many of the ancient ditches are still in use. The duty of water is heavy, as rice and sugar require more water than any other crops grown in the world. In Spain, India, Siam, etc., the average duty for cane land is from 45 to 65 acres for one second foot; for rice the duty is one second foot for from 25 to 35 acres. In Hawaii the sugar cane duty is put at one second foot for 41.6 acres, on the large plantations of the Hawaiian Commercial Company, the duty reaching as high as 65 acres. But the conclusion is reached by engineers of repute—

(1) That while the duty of water is variable with all the varying conditions of soil, climate, rainfall, wind, exposed or sheltered locality, and in some degree with the length of time the land has been irrigated, such variation is generally between the limits of 40 acres as the minimum and 90 acres as the maximum duty of 1 cubic foot per second.

(2) That economy in the application of water below a certain limit, which, for the southerly slopes of this island seems to be about an average of 1 foot in depth per month, can only be exercised at the expense of the yield of sugar.

(3) That a greater duty than 60 acres per cubic foot per second can not be counted on with safety; or, in other words, that 328,500 gallons per acre are needed monthly, or to mature a crop say 15 times that amount, or 4,927,500 gallons, are required. In estimating on the cost of pumping water for irrigation these are convenient figures to remember.

The largest artesian supply is derived from wells bored along the margin of Pearl Harbor. They are almost phenomenal in their volume and extent. They irrigate 20,000 acres of rice, and also a large area in bananas and other products, besides giving power for several large mills.

There are also a number of remarkable springs having considerable flow, 7 of them giving a total of 116 second feet. The measured flow of developed springs is on one of the islands sufficient to irrigate at least 7,000 acres of sugar cane, and probably as high as 10,000 acres. On the island in which Pearl Harbor is situated, there are 100 flowing wells, all of them bored within the past twelve years. Four of these wells would supply with water a city of 165,000 inhabitants. The wells are all confined to a marginal rim around the island back from sea level, at an elevation above it of from 21 to 42 feet. The supply seems unlimited, no diminution being observed.

THE ISLAND OF MADEIRA.

The system of irrigation management practised in the island of Madeira is quite elaborate. The whole area is only about 240 square miles, or 153,600 acres, of which over one-half is irrigated and cultivated. Most of the coastal plane is so utilized. The products are mainly sugar cane, wheat, maize, onions, sweet potatoes, pumpkins, and fruits, of which bananas are a large part. Vegetables are grown successfully at an elevation of 3,000 feet, and most of the cultivation is between 500 and 1,000 feet above sea level. Oranges flourish at 1,500 feet. The water supply is furnished by perennial springs which are filled up with the waters of the rainy season. Water rights and works are termed "levadas," a system which is at least 300 years old. There are no catchment basins or reservoirs, except such as nature has provided and the water itself has plowed and furrowed for its own passage. The "levadas" are open conduits or ditches of open masonry or rock cuts. They show skill and great labor, passing through tunnels, over bridges, or along the precipitous sides of mountains. Some of them are but a few miles while others are from 60 to 70 miles in length. These "levadas" are owned by "committees" of landowners, water being an easement of the soil. The delivery is regulated by custom, upon the horary plan. Some deliver their whole contents in an hour or two; others a quarter at a time just as the proprietors may determine. The quantity issued is considered to be the amount which will run along a furrow at any one time without washing away the soil. To illustrate, the St. Luzia levada has 4,245 hours of water. These rights attach to purchase and inheritance, and were originally acquired through construction of the levada. The managing committee annually sells this water, or rather its use, for an amount sufficient to keep the conduit in repair. Each piece of ground under the levada is entitled to its hours in rotation. When the dry season sets in, a certain period for serving the whole district, called a "gyre," is devised, and this varies from fifteen to sixty days between periods of service. The levadeiro is an official similar to the "water master," "major domo," or the "zanjero" of Utah, New Mexico, Arizona, and Southern California. He is paid by fees, the tariff of which is regulated by the levada committee, who are selected by the proprietors. The prices of a run for the season varies at different parts, rising from $5 to $8 in the neighborhood of Funchal. Government levadas have been constructed and turned over to the local bodies. It is reported that they have been allowed to fall into bad order. Water is the most valuable property in Madeira and there is a good deal of litigation over it. United States Consul, T. C. Jones,* says:

> One of the principal difficulties attending the management of the levadas was the want of a legal standing as corporate bodies of their committees. A quarrel between

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* Canals and Irrigation, Special Consular Reports, 1891; State Department.

two levadas drawing their supply from the same valley occasioned a lawsuit which has lasted now more than forty years.

Within the last few years a law has been passed enabling the committees to incorporate themselves, with power to acquire property and otherwise protect and improve their levadas. They can purchase the land containing their springs, protect the forest and the trees along their lines.

Every farmer of thrift has on his land tanks to store his water, and from these tanks little levadas distribute it when and wherever he wants it.

Water rights are held under title deeds, which specify the intervals at which the supply shall be given and the length of time it shall continue.

Water is always of ready sale. If a crop fails from any cause, the water for that land is sold to a more fortunate neighbor, though sometimes at a very reduced rate.

Under any system it is hard for the poor. Their supply is scant, and they must receive it when their time comes, seasonable or unseasonable, day or night, and without tanks they can not care for or properly distribute it.

The rainfall along the coast belt is about 28 inches per annum. An important work is now in progress by which the water collected in a gorge, considered heretofore as inaccessible, will be delivered by means of a large levada and conveyed to a fruitful valley, which has suffered from loss of its old supply. The source is 4,700 feet above the sea. After entering the valley the water will flow down a series of cascades with a fall of more than 300 feet.

A constant flow of a pint of water is sufficient to irrigate 5 acres of ground; that is, the water must flow into a reservoir and be used from that as required.

The regulation for the government levadas are interesting, especially those which related to the duty of the "care-takers."

MADAGASCAR.

Irrigation by flooding for rice culture is the only mode practiced in Madagascar. The water is applied direct through shallow channels constructed of grass and mud, or through other material that may be at hand. Water is used without restriction or cost other than the labor required in its direction. It seems to be generally accepted as community property.

EXTENT AND IMPORTANCE OF ANCIENT WATER SUPPLY AND IRRIGATION WORKS.

(The following interesting statements are from a paper read by Civil Engineer Frederick S. Gipps, before the Royal Society of New South Wales, in December, 1887.)

The numerous remains of huge tanks, dams, canals, aqueducts, pipes, and pumps in Egypt, Assyria, Mesopotamia, India, Ceylon, Phœnicia, and Italy, proved that the ancients had a far more perfect knowledge of hydraulic science than most people are inclined to credit them with. To this experience it seems to me may be contributed the construction of many of those monuments and temples immortalized by their gigantic and imperishable ruins, the astonishment and admiration of the ancient historian as well as of the modern traveler. I am partially warranted in this assumption by the fact that the Egyptians ran canals through their quarries, by which, when filled by the inundations of the Nile, they transported on rafts proportionate to their weight huge masses of stone for columns or obelisks to the positions at which they were required, the whole country being intersected with numerous canals. Without doubt the Egyptians, Chinese, and East Indians have from time immemorial raised water both for irrigation and turning mills, and it is therefore probable that, understanding its property as a motive power, they applied it in the construction of some of their magnificent temples. . . . After a careful perusal of the records of history, it appears to me impossible to assert with confidence what particular nation originated the construction of reservoirs, canals, and water machinery.

The priests of Egypt believed that all things were composed of water, whilst Thales, the Milesian, taught that all things originated from water. The first artificial lake of which there is reliable record was Lake Maeris. The historians Herodotus, Diodorous, and Pliny have described it, on the testimony of the inhabitants of the country, as one of the noblest works of the time, from its enormous dimensions and its capacity for irrigation for the benefit of mankind. According to them it was about 3,600 stadia or 413 miles in circumference, and 300 feet deep. Modern travelers have considerably reduced the circumference and depth of this lake, making it measure somewhat less than 50 miles, but even with this curtailment it must have been a magnificent engineering work, worthy the admiration of all the ages. It was constructed, some historians say, by King Maeris, others by King Amenembet III, in the twelfth dynasty, 2084 B. C. Its principal object was to regulate the inundations of the Nile River, with which it communicated by a canal about 12 miles long and 50 feet broad. When the inundation rose over 24 feet, and was likely to be disastrous to the crops, the sluices were opened and the flood was relieved, owing to their drainage through the canal into the lake; when the Nile rose only 12 feet and drought threatened the crops, the dearth was neutralized by the storage waters of the lake. As the Egyptians were so dependent on the inundation of the Nile for their welfare, even for their means of livelihood, they made careful observations by fixed measures of the height of its inundation, extending over a long series of years, from which it was ascertained that if the flood rose only 16 feet a famine was threatened, or if over 24 feet a disastrous flood might be anticipated.

Sesostris, one of the most illustrious kings of antiquity, who reigned in Egypt 1491 B. C., had a great number of canals cut for the purpose of trade and irrigation, and is said to have designed the first canal which established communication between the Mediterranean and the Red Sea. This work was continued by Darius, who abandoned it because he thought the Red Sea was higher than Egypt, and would therefore deluge the whole country, and it was finally completed under the Ptolemies. Irrigation canals are so numerous in Egypt and irrigation is conducted on such an extensive scale that it is calculated only one-tenth of the water of the Nile which enters Egypt passes through the Mediterranean Sea.

The Assyrians were equally renowned with the Egyptians from the most remote periods of history for their skill and ingenuity in the construction of hydraulic works. Through the foresight, enterprise, and energy of their rulers they converted the sterile country in the valleys of the Euphrates and Tigris into a fertility which was the theme of wonder and admiration of the ancient historians. The country below Hit, on the Euphrates, and Samarra, on the Tigris, was at one time intersected with numerous canals; one of the most ancient and important of which, called the Nahr Malikah, connecting the Euphrates with the Tigris, is attributed by tradition to Nimrod, King of Babel, 2204 B. C., whilst other historians assert that Nebuchadnezzar constructed it. It seems that during June, July, and August the volume of the river Euphrates increased so rapidly that it threatened to overflow its banks and cause considerable damage to Babylon and its neighborhood, and it was therefore considered necessary to raise high banks on both sides of the river, built of brick cemented with bilimen, to protect the city. To facilitate this purpose a big lake was dug out 42 miles in circumference and 35 feet deep, into which the whole river was turned by an artificial canal. When the embankments were completed the river was restored to its original channel, whilst the lake served as a storage reservoir for collecting flood waters and distributing them for irrigation. With the destruction of Babylon the glory of the empire departed, the canals were neglected, and the country, described by Herodotus as being prolific before all other lands in its production of corn, wheat, and barley, has become so dry and barren that it can not be cultivated. The principal canals supplied by the Euphrates were the Nahr Malikah or Fluvius Regius, the Nah-raga, the Nahr Sares, the Kutha, and Pallacopus. The Tigris supplied the Nahrawan and Dyiel, besides several small canals. The whilom great importance of the Nahrawan, both for commerce and agriculture, and its great antiquity, are testified to by the ruins of numerous towns and cities on both of its banks. It started on the right bank of the Tigris, where the river debouches from the Hamrine Hills, and flowed at a distance of 6 or 7 miles from the river toward Samarra, where it was joined by a second conduit. About 10 miles farther on it received a third feeder from the river, and then continuing its course it approached Bagdad. A few miles lower down it flowed into the Dyalah or Shirwan River, which was raised by a large band or weir to a sufficient height to allow of its continuance. It then proceeded through Kuzistan, absorbing all the streams from the Sour and Buckharee mountains, and finally flowed into the Kerkha River. It was over 400 miles long and of immense dimensions, its width varying from 250 to 400 feet, and by numerous branches on both sides it irrigated a very extensive area of country, whilst at the same time it was available for navigation. Few, if any, hydraulic schemes of modern days equal in boldness of conception this stupendous achievement of a generation of four thousand years ago. The present irrigation canals deriving their supply from the Tigris, known as the Boogharib, Massoode, Desodee, Rithwammihi, and Mahmondee are very insignificant in comparison with the Nahrawan.

The remains of reservoirs in the neighborhood of Hebron, which the Jews are supposed to have constructed in the days of Solomon, for the supply of Jerusalem, show that their designers were equally alive with most engineers of the present age to the great importance of an ample and constant supply of pure water. A large portion of the supply conduit consisted of earthern pipes cased with stone hewn out to fit them, which again were covered with rubble in cement; thus the coolness and purity of the water was perfectly preserved. The Phœnicians in the zenith of their power were celebrated for their canals, both for the supply of Carthage with drinking water and for the purposes of irrigation. Agathocles, the daring, but unfortunate, Syracusian general, who thought by his invasion of Africa to force Carthaginians to raise the siege of Syracuse, left this record of his disastrous invasion, that "the African shore was covered with gardens and large plantations, everywhere abounding in canals, by means of which they were plentifully watered. The lands were planted with vines, palms, and many other fruit trees, and the meadows were filled with flocks and herds." When the Romans invaded Carthagenian dominions fifty years later, their historian, Polybius, drew a somewhat similar picture of their fertility and high state of cultivation. But, undoubtedly, the conduit which supplied Carthage with drinking water was their most notable achievement in water-works. It derived its supply from a spring about 60 miles distant from the city, and its course cut through mountains by tunnels and crossed valleys by lofty and massive aqueducts, in one instance 125 feet high. It was 4 feet wide at the base and 6 feet high, closing at the top in the shape of a pyramid, and was sufficiently high for a man to walk in with ease. It was covered throughout, for sanitary reasons, and was constructed most substantially of masonry lined internally with cement, which has preserved it from the attacks of time so well that even now a large portion of it is used for the supply of Tunis, which derives its water from the same source.

The Grecians, judging from the ruins of large aqueducts scattered throughout their country, appear from a very remote period to have paid the greatest attention to hydraulic science. Herodotus describes an ancient conduit for supplying Samos, which had a channel 3 feet wide and which pierced a hill with a tunnel nearly a mile long. Another masonry aqueduct near Patara crossed a ravine 200 feet wide and 250 feet deep. It was constructed of masonry in cement. The stone blocks three feet cube had a bore through the center of 13 inches in diameter, and joints were formed similar to a spigot and faucet joint by the annular end of a block fitting into a recess of the opposite end of another block. The joints were secured by cement and also by iron clamps run with lead. This aqueduct had a considerable depression in the center, and appears to have been one of the first attempts to run water in an inverted siphon, proving that the ancient Greeks had a thorough knowledge of the principle that water will rise to the level of its source.

The Romans having vanquished all rival empires hastened to take advantage of the knowledge they had acquired in their conquests, and in the construction of numerous grand and beautiful public works became not only renowned for their prowess in arms, but also for their high appreciation of the arts and sciences. They appear to have been especially scrupulous as to the purity of their drinking water and as to the cleanliness of their person. To insure the first, they constructed the Aqua Martia, which was covered throughout, and to encourage the last they built numerous baths.

In the reign of the Emperor Nero, Rome was supplied by no fewer than nine large conduits, having an aggregate length of 255 miles, which delivered over 173,000,000 gallons daily. Afterwards the supply was increased to 312,500,000 gallons daily, equal to a rate of 325 gallons to each inhabitant. The Aqua Martia conduit, which alone supplied the drinking water, was 16 feet in diameter and 40 miles long. One of the principal aqueducts it crossed is remarkable for the grandeur of its dimensions, and for the skillfulness of its construction. It had to sustain three large conduits, the Julia, Sepula, and the Aqua Martia, and the greatest precaution was exercised to prevent the two first from draining into the lower one, and thus deteriorating its waters. Strabo, in alluding to the skill of the Romans in the application of hydraulics, remarks that not only were there subterranean conduits at Rome, but that all the houses had siphons or water pipes which probably could be used to extinguish accidental fires. * * * They drained the Pontine marshes, and so improved the river system that, according to their historians, there was no river in Italy that was not made useful for the purpose of commerce and the transport of troops and provisions. Not content with thus developing the resources of their own country, they studied, wherever victory led the way, to improve the condition of the vanquished by similar public works. They constructed a series of large reservoirs along the range of the hills nearly bordering on the Black Sea, from which they supplied large covered cisterns in Constantinople with a pure and constant stream of water. In France they constructed conduits to supply Lyons, Frejus, Souy, Metz, and Nismes. The first, owing to the boldness of its conception and the skillfulness of its construction, and because it is one of the first known instances of the use of metal pipes subjected to any great pressure, is worthy of more than passing notice. It was designed especially for the purpose of supplying the palace of Claudius, situated in the highest part of the town. * * * The Nismes conduit, constructed in time of Augustus, B. C. 19, which delivered 14,000,000 gallons daily, is celebrated for a magnificent aqueduct called the Pont du Gard. Humble describes it as one of the grandest monuments the Romans have left in France or any other country. * * * Again, in Spain and Portugal they supplied the towns of Segovia, Seville, Evora, and Lisbon by means of conduits of considerable length, which crossed deep valleys on aqueducts of great magnitude, which, however, present no very remarkable features worthy of further comment.

China is equally celebrated with Egypt for the great antiquity of its numerous canals. The Great or Imperial Canal is one of the most stupendous works of ancient or modern times. It is 650 miles long and connects the Hoang-Ho and Yang-tse-Kiang rivers. Its depth is seldom more than 5 or 6 feet, whilst in dry seasons it is considerably less. To regulate its fall it is provided with a number of solid wooden sluices, over which vessels are hauled by machinery and let down on the other side. * * * Its average velocity is 2½ miles per hour, and in its course it crosses several large lakes on the top of enormous dykes. It is available both for navigation and irrigation, and, together with its numerous branches, irrigates an immense area of country, thus affording millions the means of livelihood and support.

Again, in the Malay Archipelago irrigation is carried out to such perfection as to excite the astonishment of the distinguished naturalist, Mr. Wallace, who thus described it:

> It was here that I first obtained an adequate idea of one of the most wonderful systems of cultivation in the world, equaling all that is related of Chinese industry, and, as far as I know, surpassing in the labor bestowed on it any tract of equal extent in the most civilized countries of Europe. I rode through this strange garden utterly amazed and hardly able to realize the fact that in this remote and little known island, Lombock, from which all Europeans (except a few traders at the port) are jealously excluded, many hundreds square miles of irregularly inundating country have been so skillfully terraced and leveled and so permeated by artificial channels that every portion of it can be irrigated and dried at pleasure.

Many ancient native writers testify to the high estimation entertained by the inhabitants of India for water supply for irrigation purposes. The "Vishnood" declares that "no satisfaction is felt without water in the three worlds, Heaven, Hell, and Earth; therefore a wise and learned man should cause reservoirs, tanks, and wells to be made. The Yama-porans teaches that "a person in whose pond or tank there is a constant supply of water obtains perpetual felicity without doubt; and the Bhewish-Yotara-poonau exclaims: "O thou, son of Koonti, get large supplies of water made at the sacrifice of your whole property, for the man at whose reservoir the cow slakes her thirst becomes the preserver of his family."

Immense tanks or reservoirs and irrigating canals appear to have been constructed in India many centuries anterior to the advent of Christ, and some of them are probably equally as ancient as the Egyptian canals. The Cummin tank in Madras has an embankment of 102 feet high, and of considerable length. The Naggar-Sulikerrai has an embankment 84 feet high and 603 feet wide at the base, which incloses an area of 40 square miles. In Bombay the Lachura tank is about 3 miles in circumference. In Ceylon the Mincheri tank forms a beautiful lake of over 20 miles in circumference. The Kalucarri tank forms a lake 60 miles in circumference by an embankment 15 miles long and 300 feet wide at base. Many of these immense embankments consist only of well trodden clay resting on the surface of the ground, and are constructed without the application of any particular engineering skill, no puddle walls having been used to render them more water-tight.

WATERWORKS, EAST OF "ARID REGION," HAVING THEIR SUPPLY FROM ARTESIAN AND UNDERFLOW SOURCES.

ABSTRACT FROM "MANUAL OF AMERICAN WATERWORKS, 1889-'90."
("ENGINEERING NEWS.")

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Waterworks, east of arid region, having their supply from artesian and underground sources; abstract from "Manual of American Waterworks, 1889-'90" 433-449

Waterworks (east of "arid region") having their supply from artesian and underflow sources.

[The problems involved in a water supply from phreatic or sub-surface sources are of a character on which all desirable data should be presented. As a part of the study of its importance and to aid in understanding what is signified under the conception of water conservation and management, these carefully arranged tables are furnished.]

ALABAMA.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Anniston	Artesian well and springs	450,000	10,375,000	Pumping to reservoir and standpipe.	
Bessemer	Spring-fed streams	1,300,000	8,000,000	Pumping to standpipe and gravity	Estimated daily capacity 4,000,000 gallons.
Fort Payne	Springs (2)	*a*	263,000	Pumping to standpipe	
Huntsville	Spring	800,000	200,000	Pumping to reservoir	Daily flow 2,000,000 gallons.
Jacksonville	Springs	500,000	1,000,000	Gravity to and from reservoir	
Montgomery	Artesian wells	1,250,000	3,917,000	Gravity and pumping	In 1886, capacity of 6 wells was 5,000,000 gallons daily.
Selma	do	2,000,000	159,000	Pumping to standpipe and direct	
Spring Garden	Springs	1,000	60,000	Pumping to reservoir	
Talladega	Spring	40,000	138,000	Pumping to standpipe	

[*Proposed works.*—Troy: Wells; franchise granted. Uniontown: Has artesian wells.]

ARKANSAS.

Alexander	Springs	*a*	8,000	Gravity	
Brinkley	Deep well	*a*	75,000	Pumping to tank	
Hope	Artesian well	*a*	60,000	do	
Hot Springs	Springs and bayou	500,000	1,000,000	Pumping to reservoir	
Pine Bluff	Cook wells (near river)	*a*	85,000	Pumping to standpipe and direct	
Rogers	Spring			Pumping to tank	Daily capacity of springs, 875,330 gallons.
Texarkana	10 flowing Wagner wells	1,000,000	3,000,000	Pumping	10 wells to be added.

[*Works projected.*—Batesville: Has spring, with capacity 400,000,000 gallons. Beebe: Artesian well being sunk. Helena: Two wells contracted for. Monticello: Works in progress; artesian supply. Stuttgart: Driven wells proposed.]

a Data not given. The same in all other items indicated by letter *a*.

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		CONNECTICUT.			
		Gallons.	*Gallons.*		
Ansonia	Springs	*a*	*a*	Gravity from reservoir	Has other works.
Birmingham	Springs and surface water	*a*	*a*	do	Two reservoirs, 9 and 27 acres.
Canaan	Springs	*a*	*a*	do	Dam 150 feet long, 12 feet high.
State Industrial School	Springs and surface water	*a*	5,000,000	do	
Danielsonville	Spring-fed brook	*a*	16,750,000	do	
Durham	Spring	*a*	*a*	Gravity	
Kent	Springs and surface water	*a*	*a*	Gravity from reservoir	Reservoir, capacity 1½ acres.
Newington	Mountain springs	*a*	*a*	Gravity	
Norwich	Springs and brooks	1,400,000	350,000,000	Gravity from reservoir	Proposed new reservoir, capacity 1,000,000,000 gallons.
Stamford	Spring-fed lake	1,000,000	6,500,000	Gravity to and from reservoir	Lake capacity 300,000,000 gallons.
Thomaston	Springs	*a*	65,000,000	Gravity from reservoir	
Thompsonville	do			Pumping to tank	
Waterbury	Springs and surface water	1,500,000	185,000,000	Gravity from reservoir	
Windsor	Springs	15,000	8,000,000	Gravity	
		DELAWARE.			
Dover	Wells (2)	59,102		Pumping direct	
Newark	Well	50,000	186,000	Pumping to standpipe and direct	
Newcastle	Spring-fed creek	450,000	1,250,000	Pumping to reservoir	
		FLORIDA.			
Fernandina	Artesian well	20,000	113,000	Pumping to tank	
Jacksonville	Artesian wells (3)	878,207		Pumping direct	Combined flow of wells 4,700,000 gallons daily.
Melbourne	Artesian well	*a*	*a*	Gravity	
Ocala	do	50,000	130,000	Pumping to tank	
Palatka	Spring-fed stream	*b*75,000	183,000	Pumping to standpipe	
Pensacola	Artesian wells	1,000,000	459,000	do	
St. Augustine	Artesian wells (4)				
Sanford	Spring-fed lake	125,000	250,000	Gravity and pumping	
Seville	do	*a*	53,000	Pumping to tanks	
Tampa	Artesian well and spring	120,000	111,000	Pumping to tank	Spring; daily capacity 5,500,000 gallons.

[Works projected at other points.—Supply from wells or springs.]

GEORGIA.

Americus	Springs	100,000	175,000	Pumping to tank	
Athens	Springs (6)	125,000	23,366,000	Pumping to standpipe	
Atlanta	See "Remarks"				Has an artesian well that supplies 108 drinking hydrants. Main supply, river.
Bainbridge	Artesian wells	15,000	32,000	Pumping to tank	
Brunswick	do	400,000	112,600	do	
Cartersville	Springs (on river bank)	*a*	367,000	do	
Dalton	Spring	75,000	376,000	Pumping from reservoir to standpipe.	
Fort Gaines	Artesian well	12,000	21,000	Pumping to tank	
Macon	Springs	1,600,000	2,575,000	Pumping to tank and reservoir	
Rising Fawn	Spring	*a*	*a*	Gravity from reservoir	Works not completed.
Rome	Wells	350,000	230,000	Pumping to standpipe	
Savannah	Artesian wells (9), and river, if necessary.	6,000,000	4,185,000	Pumping direct	Reservoir data refers to river supply.
Thomasville	Artesian wells (2)	80,000	360,000	Pumping to standpipe	
Tybee	Artesian wells	*a*	12,000	Pumping to tank	

[*Projected works.*—Supply from wells or springs. Cordele: Has artesian well. Fort Valley: Contract let; supply artesian well. La Grange: Wells. Milledgeville: Springs. Trenton: Springs. Washington: Springs. Waycross: Bonds voted. Waynesboro: Has artesian well; daily yield 100,000 gallons.]

ILLINOIS.

Aledo	Artesian well	*a*	45,000	Pumping to tank	
Barry	do	6,000	47,000	do	Report for 1887-'88.
Bloomington	Tube and surface wells	700,000	75,000	Pumping to standpipe and direct	
Blue Island	Well	60,000	60,000	Pumping to tank	
Blue Mound	do	*a*	25,000	Pumping to tank and direct	
Buckley	do	*a*	*a*	do	
Cabery	Artesian well	1,000	45,000	do	
Canton	Artesian and surface wells	100,000	25,000	Pumping to standpipe and direct	
Carthage	Artesian well	*a*	121,770	Pumping to reservoir and direct	
Clinton	Well	90,000		Pumping direct	
De Kalb	Artesian well	60,000	60,000	Pumping to tank	
Dixon	Springs and river	200,000	*a*	Pumping to reservoir and direct	
East Dubuque	Artesian well	*a*	100,000	Pumping to reservoir	
El Paso	Well (combined surface and driven.)	6,000	36,100	Pumping to tank and direct	
Eureka	Well	15,000	36,100	do	
Freeport	Artesian wells and river (18 wells).	1,000,000	115,500	do	
Fulton	Well	*a*	100,000	Pumping to reservoir and direct	

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

ILLINOIS—Continued.

City, town, or village.	Supply (wells, springs etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Galena	Artesian well	300,000	129,250	Pumping to standpipe and direct	
Galesburg	Wells	*a*	170,000	Pumping to reservoir and direct	No report since 1884.
Geneseo	Artesian wells (2)	30,000	50,000	Pumping from reservoir	Daily yield of one well in 1887, 275,000 gallons.
Greenville	Well	100,000		Pumping direct	
Havana	Gravel beds under grounds	*a*	20,000	Pumping direct and to standpipe	
Hillsboro	Well	*a*	50,000	Pumping to tank and direct	
Hoopeston	Deep well and reservoir	*a*	30,000	Pumping to tank	
Jerseyville	Artesian well	*a*	50,000	do	
Joliet	Artesian wells and pond	1,700,000	41,900	Pumping to standpipe and direct	
Kewanee	Well	*a*	*a*	Pumping to reservoir and direct	
Lemont	Artesian well	80,000	100,000	Pumping to reservoir	Report for 1887–'88.
Lewiston	Driven well	*a*	25,000	Pumping to standpipe	
Lincoln	Wells	223,856	150,000	do	
Lockport	Artesian well	*a*	500,000	Pumping to reservoir	
Mendota	do	*a*	170,000	do	
Menouk	Well	*a*	57,000	Pumping to tank	
Monmouth	Artesian well	55,000	300,000	Pumping to reservoir	
Morgan Park	do	30,000	100,000	Pumping to tank	
Morrison	Spring	200,000	*a*	do	
Morrisonville	Well	50,000	40,000	Pumping to tank and direct	
Mount Pulaski	do	150,000	50,000	Pumping to tank	
Mount Carroll	do	32,500	*a*	do	
Norwood Park	Artesian well	*a*	*a*	Pumping from reservoir to tank	
Oak Park	Artesian wells (2)	100,000	*a*	Pumping to standpipe	
Ottawa	Springs	180,000	*a*	Gravity	
Peoria	Wells	4,000,000	889,000	Pumping to standpipes (2)	
Petersburg	Tube wells (4)	80,000	185,000	Pumping to tank	
Pittsfield	Artesian well	*a*	39,750	do	
Riverside	do	*a*	42,000	do	
Rochelle	Springs	50,000	*a*	Pumping direct	
Rockford	Artesian wells (5)	1,963,942	*a*	do	
Sandwich	Well	28,800	84,600	Pumping to standpipe and direct	
Savanna	Well (combined surface and driven).	100,000	750,000	Pumping to reservoir	
Somonauk	Well	*a*	80,000	Pumping to tank	

Sterling and Rock Falls	Artesian wells and river	200,000	235,000	Pumping to standpipe	
Streator	Tube and artesian wells and creek.	500,000	294,000	do	Artesian well for fires
Sullivan	Well	*a*	50,000	Pumping to tank	
Sycamore	do	35,000	179,000	Pumping to standpipe and direct	
Taylorsville	Surface and tube wells	*a*	30,000	Pumping to tank and direct	
Warsaw	Artesian well	*a*	*a*	*a*	Well for fires
Washington	Driven wells	*a*	21,000	Pumping to standpipe	
Waukegan	Artesian wells (3 flowing)	*a*	*a*	Gravity	
Yorkville	Springs	1,000	200,000	do	
[*Projected works* at other points; some already having artesian supply.]					

INDIANA.

Attica	Springs	9,000	*a*	Pumping to reservoir	
Bluffton	Wells (near river)	200,000	*a*	Pumping direct	
Crawfordsville	Springs (daily flow 4,000,000 gallons).	*a*	*a*	Pumping to reservoir, standpipe, and direct.	
Elkhart	Well	450,000	106,000	Pumping to tank and direct	Daily yield 600,000 gallons.
Goshen	Artesian wells (6)	500,000	*a*	Pumping direct	
Greensburg	Tube wells	*a*	*a*	do	
Hammond	Well	200,000	*a*	Pumping to standpipe	
Kendallville	do	7,000	*a*	Pumping direct	
Kokomo	Artesian wells and creek	250,000	*a*	do	
Ligonier	Well	12,000	50,000	Pumping direct and to tank	
Marion	do	250,000	*a*	Pumping direct	In 1881.
Michigan City	Springs	800,000	120,000	Pumping direct and to tank	
Muncie	Artesian wells	500,000	*a*	Pumping direct	
New Carlisle	Well	20,000	35,000	Pumping direct and to tank	
New Castle	do	*a*	*a*	Pumping	
Plymouth	Driven wells (5)	18,000	20,000	Gravity and pumping	
Richmond	Springs	1,000,000	9,000,000	Pumping to reservoir and direct	
Salem	Spring	120,000	*a*	do	In 1887.
Shelbyville	Well	2,500	*a*	Pumping to standpipe	
South Bend	Artesian wells (11)	1,750,000	500,000	Pumping from reservoir to standpipe.	
Wabash	Driven well, springs, and creek	250,000	*a*	do	Daily flow of well, estimated, 2,000,000 gallons.
[*Projected works* at other points; supply to be artesian.]					

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

IOWA.

City, town, or village.	Supply (springs, wells, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Atlantic	"Cook wells"	250,000		Pumping direct	
Audubon	Well	20,000	106,000	Pumping to tank	
Boone	Artesian wells	50,000	22,000	Pumping to tank and direct	
Cedar Falls	Springs	50,000	100,000	Pumping to tank	
Cedar Rapids	Artesian wells and river	1,000,000		Pumping direct	3 5-inch wells for domestic, and river for fire, purposes.
Charles City	Spring	a	a	do	
Cherokee	Artesian wells	a	152,000	Pumping to standpipe	
Clarinda	Driven wells	100,000		Pumping direct	
Clinton	Artesian wells (2)	1,000,000	325,000	Pumping to tank and direct	Wells 5½-inch diameter, 1,100 feet deep.
Colfax	Driven wells (3)	30,000	70,000	Pumping to reservoir	
Decorah	Well (surface)	32,000	400,000	do	Well 30 feet diameter and 30 feet deep; in gravel.
Denison	do	16,524	100,000	Pumping to tank	
Dubuque	Tunnel	a	1,750,000	Gravity	Abandoned mines drainage tunnel, 100 to 200 feet below surface.
Eldora	Combined driven and surface well.	a	100,000	Pumping to tank	6 inch driven well, 100 feet deep; in bottom of surface well 40 feet deep.
Gladbrook	Artesian well	800	30,000	do	
Hawarden	Driven wells	a	60,000	do	
Holstein	Well	a	50,000	do	
Ida Grove	Driven wells (23)	15,000	100,000	do	
Independence	Driven wells and river	200,000		Pumping direct	
Iowa City	Wells (150 feet deep)	350,000		do	
Lansing	Flowing wells (2)	50,000		Gravity	
Le Mars	Driven wells	150,000	250,000	Pumping direct (from reservoir for fires).	
Logan	Wells (2)	a	90,000	Pumping to reservoir	
Marion	Springs (2)	200,000	614,700	Pumping from reservoir to standpipe and direct.	Daily capacity of springs, 2,025,000 gallons.
Mason City	Springs (and river for fire)	185,000	150,000	Pumping direct	
Missouri Valley	Driven wells (10)	a	200,000	Pumping to reservoir	
Monticello	Artesian well	60,000	500,000	do	
Neola	Well	a	60,000	Pumping to tank and direct	
Nevada	do	a	97,000	Pumping to tank	
Newton	Artesian well	a	100,000	Pumping to reservoir	
Odebolt	Driven wells	5,000	58,000	Pumping to tank	
Red Oak	Filter gallery (and river for fire)	400,000		Pumping direct	
Reinbeck	Well	a	20,000	Pumping to tank	Report prior to 1889.

Rock Rapids	"Drive Points" (50)	*a*	37,600	Pumping to standpipe	
Sioux City	Driven wells (104 2-inch)	1,250,000	1,500,000	Pumping to reservoir	Daily yield, 2,000,000 gallons.
Sioux Rapids	Well	*a*	50,000	Pumping to tank	
State Center	Wells (2)	1,500	64,000	do	In 1887.
Tipton	Artesian well	*a*	47,000	Pumping to standpipe	
Villisca	Wells (supplied by springs)	*a*	47,000	Pumping to tank	
Vinton	Artesian well and river				
Webster City	Artesian well	75,000	58,000	Pumping to tank and direct	
West Liberty	do	*a*	*a*	Gravity	Daily yield in 1889, 170,000 gallons.

[NOTE.—Works are proposed or projected at several other places in State, with artesian wells, springs, etc., for the supply.]

KANSAS (EAST OF THE 100TH MERIDIAN).

Anthony	Driven wells (18)	160,000	150,000	Pumping to standpipe	
Argentine	Wagner wells (6)	*a*	500,000	Pumping to tank	
Blue Rapids	Wells	*a*	200,000	Pumping to reservoir	
Columbus	Artesian well	75,000	97,000	Pumping to standpipe and direct	
Council Grove	Well	25,000	*a*	do	
Girard	Artesian well	*a*	60,000	Pumping to tank	
Greenleaf	Wagner wells (8 6-inch	*a*	80,000	Pumping to standpipe	Daily yield of wells 500,000 gallons.
Hiawatha	Wells (surface)	30,000	108,000	do	
Junction City	Wells	40,000	500,000	Pumping to reservoir	Supply in 1889, 500,000 gallons daily.
Marysville	Driven wells (20 near river)	*a*	59,000	Pumping to standpipe	
Pittsburg	Artesian well	200,000	67,000	Pumping to tank and direct	
Valley Falls	Wells	2,000	70,000	Pumping to tank	
Weir	Artesian well	50,000	50,000	Pumping to tank and direct	

KENTUCKY.

Georgetown	Spring	*a*	*a*	Pumping direct	
Glasgow	do	*a*	100,000	Pumping to reservoir	
Mayfield	Deep wells	*a*	150,000	Pumping to tank	
Middleboro	Artesian wells	*a*	*a*	*a*	
Pleasant Hill	Spring	4,000	4,482	Pumping to tank	Daily flow 5,500 gallons.

[*Proposed or projected works* (supply from wells or springs)—Princeton: Artesian well. Richmond: Wells (or lake). Shelbyville: Artesian, or surface well. Standford: Large springs.]

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

LOUISIANA.*a*

City, town, or village.	Supply (wells, springs, etc.).	Consumption. *Gallons.*	Capacity of reservoir, tank, or standpipe. *Gallons.*	Mode of service (pumping or gravity).	Remarks.
Alexandria	Artesian wells				Two wells contracted for to supply 100,000 gallons daily. 1887.

MAINE.

Brunswick	Springs and river	200,000	7,625,000	Pumping to standpipe	
Diamond Island	Springs	5,000	175,000	do	
Hallowell	do	*b*	500,000	Gravity	
Houlton	Spring-fed streams	60,000	116,000	Pumping to standpipe	
Old Orchard	Spring	*b*	390,000	Gravity (pumping direct for fires)	
Rockland, Camden, and Thomaston.	Spring-fed lake	*b*	2,500,000	Gravity to reservoir	
Sanford	Springs	7,000	52,000	Pumping to tank and direct	
Skowhegan	do	*b*	275,000	Pumping to standpipe	
South Norridgewock	Spring	*b*	15,000	Pumping to tank	
Springvale	Springs	*b*	30,000	do	City has other works; supply, surface water.
York Beach	Artesian wells	*b*	25,000	do	

MARYLAND.

Annapolis	Springs and surface water	*b*	8,250,000	Pumping to reservoir	
Catonsville	Artesian well and stream	150,000	650,000	Pumping to tanks	
Chestertown	Springs	40,000	1,080,000	Pumping to reservoir	
Easton	Artesian wells	50,000	84,600	Pumping to standpipe	
Frederick	Artesian wells, springs, and mountain stream.	*b*	1,900,000	Gravity	
Frostburg	Artesian wells (4) and springs	35,000	1,000,000	do	
Hagerstown	Artesian wells and spring-fed creek.	500,000	20,000,000	do	
Mechanicstown	Mountain springs	50,000	300,000	do	

Salisbury	12 6-inch wells and river (for fire).	27,000	84,600	Pumping to standpipe and direct	
Union Bridge	Springs	50,000	480,000	Pumping from receiving to distributing reservoir.	
Westminster	Springs (3)	12,000	1,500,000	do	
[Projected works.—Cambridge: Probable supply, well.]					

MASSACHUSETTS.

Agawam	Springs	*a*	*a*	Gravity	
Amesbury	Driven wells	*a*	2,300,000	Pumping to reservoir	
Amherst	Springs and brook	*a*	2,800,000	Gravity	
Ashburnham	Springs	*a*	1,000,000	Gravity from impounding reservoir.	
Attleboro	Well and river	100,000	215,000	Pumping to tank and direct	
Avon	Spring-fed well	*a*	205,000	Pumping to standpipe and direct	
Ayer	Well	40,000	100,000	Pumping to reservoir	
Bridgewater and East Bridgewater.	Wells (near river)	300,000	270,000	Pumping to standpipe	
Brookfield	Springs	*a*	*b*	Gravity	
Canton	Well (filter)	*a*	467,600	Pumping to standpipe	
Cheshire	Spring-fed brooks	*a*	900,000	Gravity	
Chicopee	Wells and spring-fed brook	30,000	5,530.000	Gravity and pumping to tank	
Chicopee Falls	River and springs	*a*	*b*	Pumping to reservoir	
Clinton	Springs and surface water	400,000	60,000,000	Gravity from reservoir	
Cohasset	Driven wells (65 2-inch wells)	*a*	1,500,000	Pumping to reservoir	
Cottage City	Spring-fed lake (for fires only)	*a*	*b*	Pumping direct	Pumping machinery, capacity 500,000 gallons; new works—supply, springs (by gravity), in progress.
Dedham	Well (2)	180,663	540,000	Pumping to standpipe	
Easthampton	Springs and pond	60,000	600,000 Spring-fed	Pumping direct—pond, gravity, springs.	Springs furnish one-half of supply.
Franklin	Wells		423,000	Pumping to tank	
Grafton and North Grafton.	Artesian well and surface well	125,000	110,000	Pumping to standpipe	
Haverhill	Srings and ponds	1,250,000	210,000	Pumping to standpipe and gravity	
Hinsdale	Springs and brooks	*a*	40,000,000	Gravity from reservoir	
Holyoke	Spring-fed ponds	2,380,000	70,000.000	Gravity	Capacity of another reservoir not given
Hopkinton	Artesian wells (4)	40,000	250.000	Pumping to tank	
Hyde Park	Driven wells		1,500,000	Pumping to reservoir	
Kingston	Well and river	25,000	265,000	Pumping direct	Well yields 70,000 gallons daily.
Leicester	Springs and wells			Gravity	
Lenox	Springs and river	45,000	605,000	Gravity and pumping	
Malden	Driven wells and pond	1,000,000	1,096,000	Pumping to standpipe and tank; also gravity.	
Mansfield	Springs	130,000	242,000	Pumping to standpipe and direct	

a Projected

b Data not given.

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

MASSACHUSETTS—Continued.

City, town, or village.	Supply (springs, wells, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Marblehead	Driven wells	175,000	*a*	Pumping to standpipe	
Middleboro	Well	89,885	235,000	Pumping to standpipe and direct	
Milford and Hopedale	Wells and river	325,000		Pumping direct	Wells for domestic use. River for fires.
Nahant	Tubular and surface wells	30,000	*a*	*a*	Marblehead Water Co.'s plant, through a meter.
Newburyport	Wells	400,000	300,000	Pumping to tank	
North Adams	Artesian wells (2) and brook	1,200,000	10,850,000	Pumping from wells; gravity from brook.	Daily yield of wells, 800,000 gallons.
North Attleboro	Well	3,553	564,000	Pumping to standpipe	
North Easton	Well (near river)	87,000	235,000	Pumping to standpipe and direct	
Norwood	Spring-fed pond	300,000	1,400,000	Pumping to reservoir	Pond has capacity of 123,000,000 gallons.
Orange	Spring	*a*	*a*	Gravity from reservoir	
Palmer	Springs	70,000	8,000,000	Gravity to and from reservoir	
Peabody	Spring and ponds	688,346	524,000	Pumping to tank and gravity	
Quincy	Wells and storage reservoir on brook.	260,000	180,318,000	Pumping	
Revere and Winthrop	Driven and collecting wells	350,000	1,500,000	Pumping to reservoir	
Riverside	Springs	*a*	*a*	Gravity	
Salem	Spring-fed lake	2,111,272	20,000,000	Pumping to reservoir and direct	
Sharon	Well (near brook)	50,090	208,000	Pumping to tank	
Shelburne Falls	Mountain springs	9,090		Gravity	
Southbridge	Springs and surface water	25,000	*a*	do	
Stockbridge	Springs, artesian well, and surface water.	*a*	*b* 250,000	Pumping to reservoir and gravity	Impounding reservoir, capacity not given.
Stoughton	Well	25,000	317,000	Pumping to tank	
Sunderland	Springs	50,000	*a*	Gravity to reservoir	
Swampscott	Tubular wells, and surface well	400,000	*a*	*a*	Furnished by Marblehead Water Co.
Taunton	Driven wells and surface water	751,882		Pumping direct	
Uxbridge	Springs	3,000	400,000	Gravity	
Vineyard Haven	do	*a*	117,000	Pumping to standpipe	
Ware	Well	133,359	1,500,000	Pumping to reservoir	
Warren	Springs and pond	*a*	*a*	Gravity from springs, pumping from pond for fires.	60 families supplied from springs; town has several small plants.
West Brookfield	Wells and brook	*a*	*a*	Gravity	Town has 4 plants—3 supplied from wells—124 families supplied.
West Stockbridge	Spring	*a*	*a*	do	30 families supplied.
Whitinsville	Springs	*a*	300,000	Gravity from reservoir	Capacity of springs.

[*Projected works* (with artesian supply) at several other places.]

MICHIGAN.

Adrian	Artesian and surface wells	450,000		Pumping direct	
Allegan	Well (near river)	300,000		do	
Ann Arbor	Springs and surface water	500,000	9,000,000	Pumping to reservoir	
Bessemer	Springs and wells	*a*	100,000	Pumping from collecting reservoir	
Big Rapids	Driven wells	2,000,000	30,000	do	
Capac	Tubular well (sunk into rock)	*a*	15,000	Pumping to tank	
Caro	Springs	40,000	230,000	Pumping to standpipe and direct	
Cedar Springs	Well and creek	*a*		Pumping direct	Pumping machinery, capacity 150,000 gallons.
Charlotte	Wells	266,666		do	
Cheboygan	Artesian wells (2)	230,000		do	
Clare	Well	260,000		do	
Dowagiac	Artesian wells (5)	*a*	300,000	Pumping from receiving reservoir	Wells throw water 12 feet above surface.
Edmore	Tube wells (in surface wells)	8,000	75,000	Pumping to reservoir and direct	
Evart	Spring and wells	35,000		Pumping direct	
Fenton	Artesian wells	*a*	*a*	do	Pumping machinery, capacity 1,500,000 gallons.
Flint	Wells, creek, and river	762,316		do	
Fremont	Flowing artesian wells (4) and springs.	*a*	*a*	do	Pumping machinery, capacity 750,000 gallons.
Gaylord	Well	4,500	85,000	Pumping to tank	
Gladwin	Artesian wells and river	*a*	*a*	Pumping direct	Pumping machinery, capacity 1,000,000 gallons.
Grand Haven	Driven wells (2 plants)	580,000		do	
Grand Rapids	Springs and well	*a*	235,000	Pumping to standpipe and gravity (from springs).	City has other works, with supply from streams.
Greenville	Driven wells and river (for fire)	*a*	*a*	Pumping direct	Pumping machinery capacity 1,440,000 gallons; 35 2-inch wells, 1½-inch points.
Hancock	Springs	*a*	70,000	Gravity from reservoir	
Hastings	Well	300,000		Pumping direct	
Holland	Springs	150,000	*a*	Pumping from collecting reservoir	Contract let for well.
Ionia	Artesian wells (4), springs, and surface water.	300,000		Pumping direct	
Ithaca	Artesian wells	*a*	*a*		Projected works reported.
Jackson	do	1,800,000		Pumping direct	
Kalamazoo	Wells (2) (sunk on iron shoe)	1,790,660		do	
Lake Linden	Artesian well and creek	*d* 35,000		Pumping direct and gravity	
Lansing	Tile-lined wells	900,000	289,000	Pumping to standpipe	8 wells, 34 feet deep.
Lapeer	Artesian wells (3), flowing	150,000	30,000	Pumping direct (overflow goes to reservoir).	
Lowell	Driven wells (20)	*a*	*a*	Pumping to reservoir	
Manistee	Combined driven and surface wells.	700,000		Pumping direct	
Marshall	Well	*a*	235,000	Pumping to standpipe	

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

MICHIGAN—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity, reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Mount Pleasant	Combined driven and surface wells.	160,000	176,250	Pumping to tank and direct	
Muskegon	Well and river	1,300,000		Pumping direct	
Newago	Well	*a*	*a*	do	Pumping machinery capacity 750,000 gallons.
North Muskegon	Driven wells (30) and lake	250,000		do	
Ovid	Wells	100,000		do	Pumping machinery capacity 2,000,000 gallons.
Owosso	Wells or river (or both)	*a*	*a*	do	
Petoskey	Well	100,000	100,000	Pumping to tank and direct	
Pinconning	Artesian well	50,000		Pumping direct	
Pontiac	Wells and river	65,000		do	
Reed City	Well, spring, and creek	200,000		do	
St. Johns	Artesian wells	*a*	150,000	do	
St. Louis	Artesian wells (2)	*a*	*a*	do	Pumping machinery capacity 1,000,000 gallons.
Stanton	Artesian well	100,000	*a*	Pumping to reservoir	
Sturgis	Well	*a*	*a*	Pumping direct	Pumping machinery capacity 1,750,000 gallons.
Tecumseh	do	*a*	160,000	Pumping to tank	
Three Rivers	Driven wells (9, 4-inch, 96 ft. deep)	130,000		Pumping direct	
Vassar	Artesian well and river		106,000	Pumping to standpipe and direct	
Ypsilanti	Well	500,000	254,000	Pumping to tank	

[NOTE.—Works (with artesian supply) projected at other places in State.]

MINNESOTA.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity, reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
Alexandria	Driven wells	*a*	*a*	Pumping direct	Pumping machinery capacity 1,000,000 gallons.
Austin	Artesian well and river	60,000		do	Well for domestic, river for fire purposes.
Cannon Falls	Well	*a*	175,000	Pumping to reservoir	
Faribault	Wells	100,855	750,000	do	
Fort Snelling	Spring	40,000	30,000	Pumping to tank, and direct	
Lanesboro	Well (200 feet deep)	*a*	225,000	Pumping to reservoir	Report for 1887-'88.

Mankato	Artesian wells (2)	250,000	850,000	do	Daily flow in 1889, 1,500,000 gallons.
New Ulm	Well	*a*	45,000 26,000	Pumping to reservoir (thence to tank).	
North St. Paul	Artesian wells and lake	3,000	51,000	Pumping direct and to standpipe	
Pipestone	Bored well (200 feet deep)	5,000	90,000	Pumping to standpipe	
Rochester	Springs	40,000	225,000	do	
St. Peter	Well (near river)	*a*	151,000	do	
Sandstone	Springs (5)	*a*	2,000,000	Gravity to and from reservoir (probably).	
Winona	Wells (50 feet deep, near river)	1,184,634	*a*	Pumping to standpipe	

[NOTE.—Works projected at other points; supply artesian, wells being bored in several places; unfinished at date of manual.]

MISSISSIPPI.

Biloxi	Artesian wells.	*a*	*a*	Gravity	Capacity of one well 150,000 gallons daily.
Columbus	Artesian wells (2)	300,000	40,000	Pumping to reservoir	
Meridian	Springs and surface water	400,000	200,000,000		Wells flow from 50 to 75 gallons per minute.
Pass Christion	Artesian wells	*a*	*a*	*a*	

[Note—Works projected at other places; several already have wells.]

MISSOURI.

Carrollton	Driven wells	100,000	93,000	Pnmping to standpipe and direct	
Clinton	Artesian well	*a*	2,080,000	Pumping to reservoir standpipe and direct	
Fulton	Artisan well	*a*	100,000	Pumping and gravity	
Marshall	Well	250,000		Pumping and direct	
Mexico	Springs and surface water	250,000		do	
Springfield	Spring	1,000,000	4,065,000	Pumping to reservoir tank and direct	
Trenton	River and well	200,000	170,000	Pumping to standpipe and direct	

[NOTE.—Works projected at other piaces; supply artesian.]

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

NEBRASKA (EAST OF 97°).

City, town, or village.	Supply (springs, wells, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Ashland	Wells (2 70 feet deep)	16,000	65,000	Pumping to tank	
Blair	Tube wells (30)	50,000	700,000	Pumping to reservoir	
Fremont	Driven wells	75,000	30,000	Pumping to standpipe and direct	New system (Godfrey's), 50 2-inch wells (5 batteries, 10 wells each). Direct-pumping; yield, 2,400,000 gallons. [Eng. News, Nov. 7, 1891.]
Lincoln	Driven wells (100) and surface well.	1,500,000	140,000	Pumping to standpipe	
Pawnee City	Wells (2 7-inch)	*a*	80,000	Pumping to standpipe and direct	
Wahoo	Driven wells and river	200,000		Pumping direct	
Weeping Water	Wells	*a*	170,000	Pumping to reservoir	
West Point	Driven wells (24)	112,000	110,000	Pumping to reservoir and direct	
Wisner	Well	*a*	90,000	Pumping to tank	
Wymore	Wells	*a*	93,000	Pumping to standpipe	

[NOTE.—Works projected at other places, some already having wells.]

NEW HAMPSHIRE.

City, town, or village.	Supply (springs, wells, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
Bethlehem	Springs	150,000	250,000	Gravity from reservoir	
Dover	Springs and pond	*a*	2,000,000	Pumping to reservoir	
Drewsville	Spring	*a*	*a*	Gravity	Bored logs (for pipes) laid in 1804, still in use.
Farmington	Springs	*a*	*a*	Pumping to reservoir	
Gorham	do	27,000	6,500	Gravity	
Hanover	Springs (8)	10,000		do	
Lancaster	Springs	*a*	*a*	do	
Plymouth	do	50,000	4,000,000	do	
Portsmouth	Springs (20)	*a*	500,000	Pumping to reservoir and gravity	Report for 1887-'88.
West Canaan	Spring	*a*	*a*	Gravity	
The Weirs	Spring and wells	*a*	*a*	*a*	

[NOTE.—Works proposed and projected at several other places.]

NEW JERSEY.

Asbury Park	Artesian wells	a	105,000	Pumping to standpipe	
Atlantic City	do	500,000	198,750	Pumping to standpipe and direct	City has another plant with supply from other sources.
Blairstown	Spring	a	112,000	Pumping to standpipe	
Bridgeton	Springs, well, and lake	261,361	4,350,000	Pumping to reservoir	
Dover	Springs	10,000	6,000,000	Gravity from collecting reservoir	Daily flow of springs, 300,000 gallons.
East Orange and Bloomfield.	Springs and wells	650,000		Pumping direct	
Flemington	Springs and river	a	a	Pumping and gravity	
Gloucester City	Springs and creek	75,000	2,145,000	Pumping from reservoir to standpipe.	
Haddonfield	Spring-fed stream	20,000	2,145,000	do	
Lawrenceville School	Well	7,500	50,000	Pumping to standpipe	
Little York	Spring	a	a	Gravity	
Long Branch	Springs and brook	710,000	152,000	Pumping to standpipe	
Merchantville	Stream fed by springs	26,354	847,600	do	
Montclair	Wells	200,000	282,000	Pumping to tank	
Moorestown	Spring-fed streams	18,000	70,000	Pumping to tank and direct	
Morristown	Springs	275,000	19,400,000	Gravity	
Newark	Tubular wells (70) and river	13,531,356	44,000,000	Pumping to reservoir	
New Jersey Reform School at Jamesburg.	Springs	25,000	28,200	Pumping to standpipe and direct	
Ocean Grove	Artesian wells (15)	400,000	215,000	Pumping to tank	
Pennington	Spring	15,000	600,000	Gravity	
Perth Amboy	Springs and surface water	350,000	20,167,000	Pumping from reservoir to standpipe.	
Phillipsburg	Well	300,000	2,000,000	Pumping to reservoir	
Princeton	do	60,000	141,000	Pumping to tank	Ground water.
Redbank	do	125,000	800,000	Pumping to reservoir and direct	In 1887.
Riverton and Palmyra	Well (near river)	25,000	70,000	Pumping to tank	
Salem	Well and surface water	300,000	42,000,000	Pumping from reservoir	
Seabright	Artesian wells (9)	100,000	67,680	Pumping to standpipe	
Short Hills	Springs	40,000	4,000,000	Pumping to reservoir	
Summit	Wells	a	183,000	Pumping to standpipe	
Vineland	Driven wells	175,000	79,000	Pumping to tank	Report for 1887-'88.
Wenonah	Springs	25,000	59,000	Pumping to tank and direct	

[NOTE.—Works proposed or projected at other places—some having already an artesian supply.]

NEW YORK.

Adams	Springs	31,249	55,000	Pumping to standpipe and direct	
Albany	Driven wells and creek	a	156,000,000		Estimated wells supply, 15,000,000 gallons daily.
Albion	Wells	a	250,000	Pumping to standpipe	
Andes	Spring	3,000	119,000	Gravity	

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

NEW YORK—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity, reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Attica	Springs	225,000	12,000,000	Gravity	
Avoca	Springs and creek	*a*	1,000,000	do	
Bainbridge	Artesian wells, springs, and reservoir.	*a*	*a*	do	2 reservoirs; 1 has area of 15 acres.
Ballston Spa	Springs	600,000	*a*	do	
Bath	Wells and springs	100,000	305,000	Pumping to standpipe	
Brooklyn	Open wells and Andrews driven wells.	49,801,701	181,000,000	Pumping to resevoirs (3)	Estimated present supply from Andrews system of wells, 15,000,000 gallons daily.
Cambridge	Springs	40,000	7,000,000	Pumping from collecting reservoir	
Canajoharie	do	*a*	*a*	Gravity	
Canastota	do	*a*	7,000,000	do	
Canisteo	do	*a*	2,000,000	do	
Castile	do	*a*	233,000	do	
Chateaugay	Spring	*a*	*a*	do	No report for 1889-'90.
Chatham	Andrews gang wells	300,000	1,500,000	Pumping to reservoir	
Clyde	Springs	*a*	200,000	Pumping to standpipe	
Cobleskill	Springs and surface water	*a*	120,000	Gravity	
College Point	Springs	450,000	*a*	Pumping from improved reservoir	
Corning	Springs and creek	350,000	3,500,000	Pumping and gravity	
Cortland	Springs	300,000	375,000	Pumping to tank	
Cuba	do	*a*	700,000	Gravity	
Davids Island	Artesian wells (2)	5,000	47,000	Pumping to tank	
Elizabethtown	Springs	*a*	*a*	Gravity	
Far Rockaway	Gang wells (50)	600,000	294,000	Pumping to standpipes (2)	Report for 1887-'88.
Flatbush	Wells (Stephens system)	750,000	239,700	Pumping to standpipe	12 wells, 8 feet diameter, 36 feet deep.
Flushing	Bored wells (17) and pond for fires.	600,000	None.	Pumping direct	
Fonda	Springs	100,000	2,000,000	Gravity	
Fort Edward	do	*a*	*a*	do	
Fort Plain	do	*a*	15,000,000	do	
Fulton	do	200,000	188,000	Pumping to standpipe	
Fultonville	do	20,000	165,000	Gravity and pumping	2 reservoirs; but 1 noted.
Garden City	Well (35 feet deep)	500,000	None.	Pumping direct	
Geneva	Springs	*a*	*a*	Pumping and gravity	
Glens Falls	do	*a*	79,000,000	Gravity from reservoirs (2)	
Gloversvile	Springs and creek	500,000	16,000,000	Gravity from reservoirs (4)	
Goshen	Springs	*a*	46,000,000	Gravity from reservoirs	
Gowanda	Springs	115,000	3,000,000	Gravity	

Gravesend	Wells (Stephens system)	2,000,000	411,000	Pumping to standpipe and direct	
Greenbush	Well and river	323,466	293,700	Pumping to standpipe	
Greenport	Driven wells (4)	a	200,000	Pumping to reservoir	Yield of wells in 1889, 1,000,000 gallons daily.
Greenwich	Springs	a	2,000,000	Gravity from reservoir	
Groton	do	a	400,000	Gravity	
Hancock	do	a	3,000,000	Gravity from reservoir	
Herkimer	Driven wells	80.000	500,000	Pumping to tank	
Homer	Springs	855,542	150,000	do	
Honeoye Falls	Wells	a	1,000	do	
Hoosick Falls	do	180,000	329,000	do	
Irvington	Artesian well and stream	15,000	9,000,000	Pumping to reservoir	
Islip	(6-inch) wells	a	352,000	Pumping to standpipe	
Jamaica	(6-inch) wells (6)	500,000	795,000	Pumping to tank	
Jamestown	Artesian wells	750,000	None.	Pumping direct	4 8-inch wells yield 2,000,000 gallons daily.
Johnstown	Springs and streams	500,000	10,000,000	Gravity from reservoir	Capacity of 2 reservoirs not given.
Little Valley	Springs	a	1,000,000	Gravity	
Long Island City	Driven and dug wells	a	a	Pumping direct	
Lyons	Wells	90,000	117,000	Pumping to standpipe	
Malone	Springs	250,000	1,600,000	Gravity to and from reservoir	
Manlius	do	a	a	Gravity	Small system.
Middletown	Springs and surface water	a	3,000,000	Pumping to reservoir and gravity	
Moravia	Springs	a	150,000	Gravity	
Mount Morris	Springs (9)	75,000	800,000	do	
Newark	Springs	100,000	1,438,000	Pumping to standpipe from collecting reservoir.	
New Berlin	do	25,000	14,000,000	Gravity	Report of 1887-'88.
New Brighton and Port Richmond.	Driven wells (40)	1,800,000	750,000	Pumping to reservoir and direct	
Nunda	Springs	60,000	a	Gravity (and pumping for reserve)	
Nyack	Springs and river	80,000	2,000,000	Gravity and pumping	
Olean	Well	650,000	2,500,000	Pumping to reservoir	Well has 20 3-inch pipes driven in bottom.
Oneida	Springs	a	22,350,000	Gravity from reservoir	
Otego	Springs and creek	a	40,000	Gravity	
Patchogue	Wells (6-inch pipe)	500,000	235,000	Pumping to standpipe	
Phelps	Springs			Gravity	
Phœnix	Wells, springs, and river	100,000	188,000	Pumping to standpipe	
Port Byron	Well	5,000	800,000	Pumping to reservoir	
Randolph	Spring	a	500,000	Gravity	
Round Lake	Springs	40,000	170,000	Pumping to tanks	
Sag Harbor	Wells	a	235,000	Pumping to standpipe	
St. Johnsville	Springs	a	a	Gravity	
Salamanca	Springs and surface water	300,000		Gravity and pumping	
Sandy Hill	Spring-fed brook	100,000	228,360	Pumping to standpipe	Daily capacity of brook, 750,000 gallons.
Saratoga Springs	Spring-fed lake	3,000,000		Pumping direct	
Schenevus	Springs	600,000	a	Gravity	
Sea Cliff	Driven wells (7)	a	28,000	Pumping to tank	
Springville	Springs	a	375,000	Pumping from collecting reservoir	
Stapleton and Edgewater	Driven wells	a	a	Pumping direct	

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

NEW YORK—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Syracuse	Springs and surface water	6,000,000	80,000,000	Pumping to reservoir and gravity	
Tarrytown	Well	*a*	1,400,000	Pumping to reservoir and tank	Well in swamp.
Unadilla	Springs	100,000	2,000,000	Pumping and gravity	
Warrensburg	Spring-fed stream	*a*	*a*	Gravity	
Warsaw	Springs	*a*	4,500,000	do	
Waverly	Springs and surface water	500,000	93,000,000	do	
Whitehall	Springs	200,000	5,500,000	Gravity and pumping	
White Plains	do	26,480	275,000	Pumping to standpipe	
Whitesboro	do	*a*	*a*	Gravity from reservoir	
Whitesville	do	*a*	35,000	Gravity to reservoir	

NORTH CAROLINA.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
Asheville	Springs, river, and surface water.	300,000	1,113,000	Pumping and gravity to reservoir and stand pipe.	
Charlotte	Springs	300,000	10,190,000	Pumping from imp. reservoir to stand pipe.	
Concord	Spring	*a*	*a*	Pumping to tank	Daily capacity of spring, 30,000 gallons.
Fayetteville	do	86,000	6,000	Gravity to and from reservoir	
Greensboro	Springs and creek	150,000	100,000	Pumping to tank	
Hendersonville	Spring	*a*	*a*	Gravity	Reservoir being built.
Newberne	Artesian well	*a*	*a*		Well, but works not yet built.
Salem	Wells (near creek)	50,000	450,000	Pumping to reservoir	Wells (2) have capacity of 40 and 50 gallons per minute.
Salisbury	Springs	84,400	*a*	Pumping to tank	
Winston	Wells (2)	120,000	1,000,000	Pumping to reservoir	One well yields daily 144,000 gallons.

[NOTE.—Works projected at other points—supply, springs, or wells.]

OHIO.

Akron	Well	1,500,000	3,500,000	Pumping to reservoir	
Ashtabula	Wells and tubes (on lake shore)	*a*	10,235,000	Pumping	
Athens—insane asylum	Well	125,000	400,000	Pumping to reservoir	
Bellefontaine	Flowing wells (2) and springs	500,000	9,000,000	Pumping and gravity	
Bucyrus	Well, filtered	265,000		Pumping direct	
Canton	Wells, lake, and creek	1,100,000		do	
Chillicothe	Well, near river	700,000	3,500,000	Pumping to reservoir	
Clyde	Wells, in bottom of settling reservoir and reservoir on creek.	50,000	*a*	Pumping direct	
Crestline	Springs	50,000	1,500,000	Gravity from reservoir	
Dayton	Tube wells (30 8-inch)	1,988,000		Pumping direct	
Delaware	Wells and springs	*a*	235,000	Pumping direct and to standpipe	
East Palestine	Drilled wells (4)	*a*	300,000	Pumping to reservoir	
Franklin	Driven wells (6)	*a*	*a*	Pumping direct	
Fremont	Springs (mainly)	533,285	2,867,000	Pumping from reservoir to standpipe.	
Galion	Wells	*350,000	*a*	Pumping to standpipe	
Granville	Driven wells	25,000	95,000	Pumping to tank	
Hamilton	Wagner wells (steam filter)	800,000	6,703,885	Pumping to reservoir and direct	
Kenton	Well	700,000		Pumping direct	
Lancaster	Well and gallery	200,000	133,000	Pumping to tank	Report for 1887-'88.
Leetonia	Spring	*a*	500,000	Pumping and gravity	
London	Cook wells	*a*	293,000	Pumping to standpipe and direct	
Mansfield	Flowing artesian wells (5) and springs (2).	1,250,000		Pumping direct	
Marietta	Well (near river)	*a*	698,000	Pumping direct and to standpipe	
Marion	Water-bearing gravel stored in reservoir.	*a*	15,330,480	Pumping to standpipe	
Middletown	Well	500,000		Pumping direct	In 1887.
Minerva	Well (near creek)	27,000	*a*	Pumping to tank	
Mount Gilead	Springs (2)	*a*	*a*		
Mount Vernon	Artesian well and surface well	375,000	205,000	Pumping to standpipe.	
National Military Home (near Dayton).	Tubular wells (6)	400.000	*a*	Pumping to reservoir and tank	
Newark	Wells (2) (in gravel)	589.900	3,000,000	Pumping to reservoir	
New Lisbon	Artesian wells (4) and springs	55.000	400,000	do	
New Philadelphia	Wells and river	250.000	2,500,000	do	
Oberlin	Springs	*a*	5,000,000	Pumping direct	
Painesville	Wells and springs	300,000	169,000	Pumping to standpipe and direct	
Salem	Artesian wells and springs	200,000	912,000	Pumping from reservoir to standpipe.	
Sidney	River and wells	9,000	212,000	Pumping to standpipe	
Springfield	Springs	2,000,000	592,000	Pumping from reservoir to standpipe.	
Troy	Well	24,000	*a*	*a*	
Upper Sandusky	Springs	*a*	200,000	Pumping to standpipe and direct	

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

OHIO—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Urbana	Well	700,000		Pumping direct	
Wadsworth	Flowing springs (4)	*a*	*a*	Gravity	
Washington Court House	Battery of wells	*a*	294,000	Pumping to standpipe and direct	
Waynesburg	Springs	*a*	*a*	Gravity	Small system.
Wooster	Springs and well	150,000	12,000,000	Gravity and pumping	
Xenia	Springs	300,000	3,281,000	Pumping direct and to standpipe	
[NOTE.—Works projected at other points: Supply wells or springs.]					

PENNSYLVANIA.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
Adrian Mines	Artesian well	4,000	3,700	Pumping to tanks	
Allentown	Springs	2,400,000	432,000	Pumping to reservoir and standpipe.	
Bedford	do	*a*	2,000,000	Gravity	
Bellefonte	do	500,000	290,000	Pumping to reservoir	
Bethlehem	Spring	650,000	968,000	Pumping direct with tanks	Works began 1754. See notes in Manual, p. 221.
Birdsboro	Spring-fed stream	30,000	25,000,000	Gravity from reservoir	
Boyertown	Springs	*a*	25,000	Pumping from reservoir	
Carbondale	do	150,000	36,000,000	Gravity from storage reservoir to distributing reservoir.	From report for 1887-'88.
Centralia	Springs on mountain	50,000	*a*	Gravity	4 reservoirs, capacity not given.
Coatsville	Spring-fed stream	120,000	3,000,000	Gravity from collecting to distributing reservoir.	
Columbia	Spring and river	400,000	5,000,000	Gravity and pumping	
Connellsville	Springs	600,000	20,000,000	Gravity from imp. reservoirs, 2	
Downington	do	*a*	8,127,000	Gravity from reservoir (3)	
Doylestown	do	80,000	530,000	Pumping to reservoir and direct	
Dubois	Springs (6)	*a*	2,000,000	Gravity to and from reservoir	
East Brady	Springs	*a*	372,000	Pumping to tank	
Ebensburg	Artesian well and pond	*a*	150,000	Pumping to reservoir	
Edenburg	Well	8,000	40,000	Pumping to tank	
Emans	Springs (2)	*a*	300,000	Gravity to and from reservoir	
Emlenton	Springs and river	*a*	325,000	Gravity and pumping	
Emporium	Springs	*a*	1,800,000	Gravity	
Ephrata	do	1,000	60,000	do	

Franklin	Springs and creek	800,000	17,000,000	Gravity and pumping	In 1887.
Freeland	Artesian well	200,000	300,000	Pumping to reservoir and direct	
Gettysburg	Driven well	60,000	140,000,000	do	
Greenville	Springs	a	8,000,000	Gravity	
Hanover	Mountain springs	50,000	4,000,000	Gravity from reservoir	
Hazleton	Springs	500,000	25,000,000	Gravity and pumping	
Jenkinton	Artesian wells (2)	a	100,000	Pumping to tank	
Jersey Shore	Springs and surface water	500,000	2,500,000	Pumping to reservoir	
Johnstown	Springs	10,000		Gravity	Has two plants, one from mountain streams.
Kennett Square	Springs and surface water	a	83,000	Pumping to reservoir and standpipe.	
Knox	Well	1,500	28,000	Pumping to tanks (2)	
Langhorne	Springs	35,000	175,000	Pumping from reservoir to tank	
Landsdale	Artesian well	a	58,000	Pumping to tank	
Lehighton	do	a	600,000	Pumping to reservoir	
Lewistown	Artesian wells (2), springs and creek for emergency.	a	500,000	Pumping and gravity	
Lititz	Springs	a	9,375	Pumping to tank	
Mahanoy City	Springs and mountain stream	400,000	45,000,000	Gravity from reservoir	
Manheim	Spring-fed creek	200,000	800,000	Pumping to reservoir	
Mechanicsburg	Springs and artesian well	74,000	1,850,000	Gravity and pumping	Daily capacity of well: flowing, 1,500 gallons; by pumping, 75,000 gallons.
Meshoppen	Springs and brook	5,000	63,000	Gravity	
Meyersdale	Spring	a	1,000,000	do	
Millerstown	Artesian well	40,000	92,000	Pumping to tanks	City has two tanks—others private.
Minersville	Mountain springs	120,000	a	Gravity	
Mount Carmel	Springs	50,000	5,000,000	do	Report for 1887-'88.
Nazareth	do	15,000	194,000	Gravity and pumping to reservoir	
Newtown	Artesian wells (2)	20,000	65,000	Pumping to reservoir	
North Clarendon	Artesian well	a	35,000	Pumping direct and to tank	
North East	Springs	50,000	a	Gravity	
North Wales	Artesian wells (2)	a	56,000	Pumping through mains to tank	
Oil City	Springs and river	a	2,500,000	Gravity and pumping to reservoir	Do.
Oxford	Bored wells (2)	40,000	500,000	Pumping to reservoir	
Pen Argyl	Spring	a	1,000,000	Gravity	
Petrolia	Artesian well	1,600	48.000	Pumping to tank and direct	Yield of well in 1883 200,000 gallons daily.
Philadelphia	Well and spring (Chestnut Hill Works.	a	a	Pumping	Daily capacity 750,000 gallons. City has several other works.
Plymouth	Springs and surface water, artesian well and river.	650,000	9,300,000	Gravity from improved reservoir pumping to reservoir.	Yield of well in 1886, flow 20,000 gallon daily; by pumping 150,000 gallons daily.
Reading	Springs (3) and creeks (2)	3,500,000	154,250,000		Minimum daily flow of springs 250,000 gallons.
Reynoldsville	Springs	1,600	72,000	Pumping to tanks	
Ridley Park	Artesian wells and lake	a	75,000	Pumping to tanks and direct	
Royersford and Spring City.	Artesian wells	a	184,000	Pumping to standpipe	
St. Petersburg	Springs	20,000	117,000	Gravity	
Schuylkill Haven	do	a	8,000,000	Gravity and pumping	

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

PENNSYLVANIA—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Sewickly	Springs and wells	150,000	4,000,000	Gravity and pumping	
Shickshinny	Spring-fed creek	300,000	*a*	Gravity	
Shippensburg	Mountain springs	100,000	700,000	do	
Slatington	do	324,000	*a*	do	
Smethport	Springs	*a*	375,000	do	
South Easton	Tunnel in mountain	40,000	750,000	do	Daily yield, 70,000 gallons
Stroudsburg	Springs	6,000	*a*	do	
Sunbury	Springs and surface water	750,000	4,700,000	Pumping from imp. reservoir to distributing reservoir.	
Tarentum	Springs	30,000	500,000	Pumping to reservoir	
Tidioute	Spring-fed streams	*a*	520,000	Gravity	
Tioga	do	300,000	15,000,000	Gravity and pumping	
Titusville	Wells (3)	1,000,000		Pumping direct	Report for 1887-'88.
Tremont	Springs and mountain stream	20,000	1,000,000	Gravity	
Troy	Springs	200,000	*a*	do	
Tunkhannock	Spring and river	*a*	600,000	Pumping to reservoir	
Ulysses	Springs	*a*	71,000	Gravity and pumping	
Uniontown	do	*a*	24,000,000	Gravity from reservoir (3)	
Walston	Artesian wells (2) and river	2,000	12,000	Pumping to tanks	
Waynesboro	Mountain springs			Gravity	
Weatherly	Springs and creek	25,000	250,000	do	
Wellsboro	Springs	*a*	70,000	Gravity to and from reservoir	
West Chester	Spring-fed creek	400,000	2,500,000	Pumping to reservoir	
York	Springs and surface water	600,000	11,000,000	do	
Austin	Springs, wells, and brooks	*a*	*a*	Pumping	
Bangor	Spring	*a*	*a*	Gravity	
Berwick	Spring (near river)	*a*	*a*	Pumping to reservoir	
Mauch Chunk and East Mauch Chunk.	Springs	*a*	*a*	Gravity	
Milford	Spring	*a*	*a*	do	
Minooka	Spring reservoir	*a*	*a*	do	
Shenandoah	Mountain springs	*a*	*a*	do	
Susquehanna	Springs	*a*	*a*	do	

RHODE ISLAND.

Drownville	Well and pond	6,000	52,000	Pumping to tank	

SOUTH CAROLINA.

Charleston	Artesian wells (3)	1,000,000	13,170,000	Pumping to standpipe and gravity to reservoir.	To standpipe for domestic use. Water passes to reservoir for fire.
Columbia	Springs and rivers	600,000	6,500,000	Pumping to reservoir	
Orangeburgh	Artesian wells (2)	*a*	35,000	Pumping to standpipe	

[*Projected works.*—Bamberg: Has an artesian well; daily yield 275,000 gallons. Barnwell: Has artesian well with daily yield in 1889 of 275,000 gallons; works authorized. Batesburg: Artesian wells proposed.]

TENNESSEE.

Athens	Springs	*a*	50,000	Pumping to standpipe	
Bristol	do	200,000	100,000	Pumping to tank	
Jackson	Bored wells (22)	500,000		Pumping direct	
Manchester	Large spring	10,000		do	
Memphis	Artesian wells (38)	8,000,000	375,000	Pumping direct and to standpipe	
Monteagle	Spring	*a*	30,000	Pumping to tank	
Murfreesboro	Spring-fed creek	*a*	*a*	Pumping direct	
South Pittsburg	Springs			Pumping and gravity	

[*Proposed works*—Covington: Has spring with yield of 75 gallons per minute; contract for works made. Fayetteville: Franchise granted; supply from springs or river. Newbern: Has 6-inch wells; surveys made. Sherman Heights: Has large spring. Tullahoma: Has springs. Union City: Franchise and contract granted; supply wells.]

VERMONT.

Bellows Falls	Lake (fed by springs)	*a*	*a*	Gravity	
Bennington	Springs	*a*	*a*	do	
Brandon	Pond (fed by springs)	*a*	*a*	do	
Brattleboro	Springs	50,000	7,500,000	do	
Fairhaven	Pond (fed by springs)	45,000	*a*	do	
Hyde Park	Springs	7,000		Gravity and pumping	
Island Pond	do	30,000		Gravity	
Montpelier	do	*a*	*a*	do	Has two systems of work. Supply from one pond.

Waterworks (east of "arid region") having their supply from artesian and underflow sources—Continued.

VERMONT—Continued.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
		Gallons.	*Gallons.*		
Morrisville	do	a	a	Gravity	
Northfield	do	a	a	do	
Richford	do	a	1,000,000	do	
St. Johnsbury	do	a	a	do	City has another system. **Supply, a** river.
Springfield	Springs (4)	4,800			
Waterbury	Springs	a	a	do.	
West Randolph	Springs and brooks	a	1,000,000	do	
Winooski	Springs	160,000	5,000,000	do	

VIRGINIA.

City, town, or village.	Supply (wells, springs, etc.).	Consumption.	Capacity of reservoir, tank, or standpipe.	Mode of service (pumping or gravity).	Remarks.
Charlottesville	Springs and surface water	10,000	192,000,000	Gravity from reservoir	
Chatham	Springs	1,000	67,500	Gravity	
Crewe	Springs (4)	125,000	40,000	Pumping to tank	
Fortress Monroe	Driven wells ($1\frac{1}{2}$-inch points)	20,000	72,000	do	
Fredericksburg	Two systems, one from springs; no data.				
Gordonsville	Springs	a	800,000	Gravity	
Hampton	Gang wells, (National Soldiers' Home).	200,000	a	Pumping direct	
Harrisonburg	Artesian wells	a	1,000,000	Pumping to reservoir	
Leesburg	Spring	a	a	Gravity	For fires all streets **have cisterns; capacity, 8,000 to 10,000 gallons.**
Lexington	Springs	90,000	2,508,000	do	
Liberty	Mountain spring	150,000	a	do	
Marion	Springs	a	a	Gravity to standpipe	
Roanoke	Spring (on mountain)	1,350,000	2,500,000	Pumping to reservoir and direct	
Salem	Springs	40,000	250,000	Pumping to reservoir	
Staunton	10 springs (in limestone)	880,000	2,500,000	Pumping to and from reservoir	Report for 1887–'88.
Tazewell	Spring	a	35,000	Gravity	
Winchester	do	a	a	do	No report for 1889–'90.
Wytheville	Large spring	a	1,000,000	Pumping to and from reservoir	

[Works projected—Pulaski City: Has two artesion wells.]

			WEST VIRGINIA.		
Bluefield	Springs	80,000	50,000	Gravity	
Martinsburg	do	300,000		Pumping direct	
			WISCONSIN.		
Appleton	Artesian wells (3) and river	600,000	2,500,000	Pumping direct	
Baraboo	Springs	60,730	275,000	Pumping to standpipe	
Bayfield	do	*a*	350,000	Gravity	Proposed increase of reservoir capacity to 1,500,000 gallons.
Beaver Dam	do	40,000	*a*	Pumping to standpipe	
Beloit	Well, 30 feet diameter, 40 feet deep.	500,000	100,000	Pumping to tank and direct	
Black River Falls	Driven wells, 48 2-inch points	50,000	150,000	Pumping to standpipe	
Burlington	Artesian wells	*a*	70,000	do	
Darlington	Well	12,000	115,000	Pumping to reservoir	
Depere	Artesian well (flowing)	*a*	*a*	Gravity	
Eau Claire	Springs	1,000,000	20,000,000	Gravity and pumping	
Fond du Lac	Artesian wells (4)	1,000,000	3,000,000	Pumping direct and storage reservoir for fire.	
Green Bay and Fort Howard.	Artesian wells (2)	300,000	900,000	do	**Flow of wells, 300 gallons per minute.**
Hudson	Artesian well	50,000	300,000	Pumping to underground reservoir	
Janesville	do	*a*	1,050,000	Pumping to standpipe and direct	
Kenosha	Artesian wells (4)	400,000	*a*	Gravity	
Madison	Artesian wells (8)	704,050	255,000	Pumping to standpipe with storage reservoir.	
Menominee	Springs and river	75,858	88,000	Pumping to standpipe and direct	
Oshkosh	Artesian wells and lake	1,200,000	*a*	Pumping direct	
Prairie du Chien	Artesian well	*a*	*a*	Gravity	
Racine *b*					**Prior to 1887 had 2 artesian wells each yielding daily 550,000 gallons. New works in 1887. Supply, Lake Michigan. Not known if well supply is now used.**
Richland Center	Artesian well	*a*	600,000	Pumping to reservoir	
Waukesha	Artesian well (1) and surface wells (2).	100,000	330,000	Pumping to standpipe and direct	
Wausau	Well	438,249		Pumping direct	
West Depere	Artesian well	*a*	*a*	Gravity	No report for 1889-'90.
Whitewater	do				**Daily yield in 1889 of 500,000 gallons.**

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